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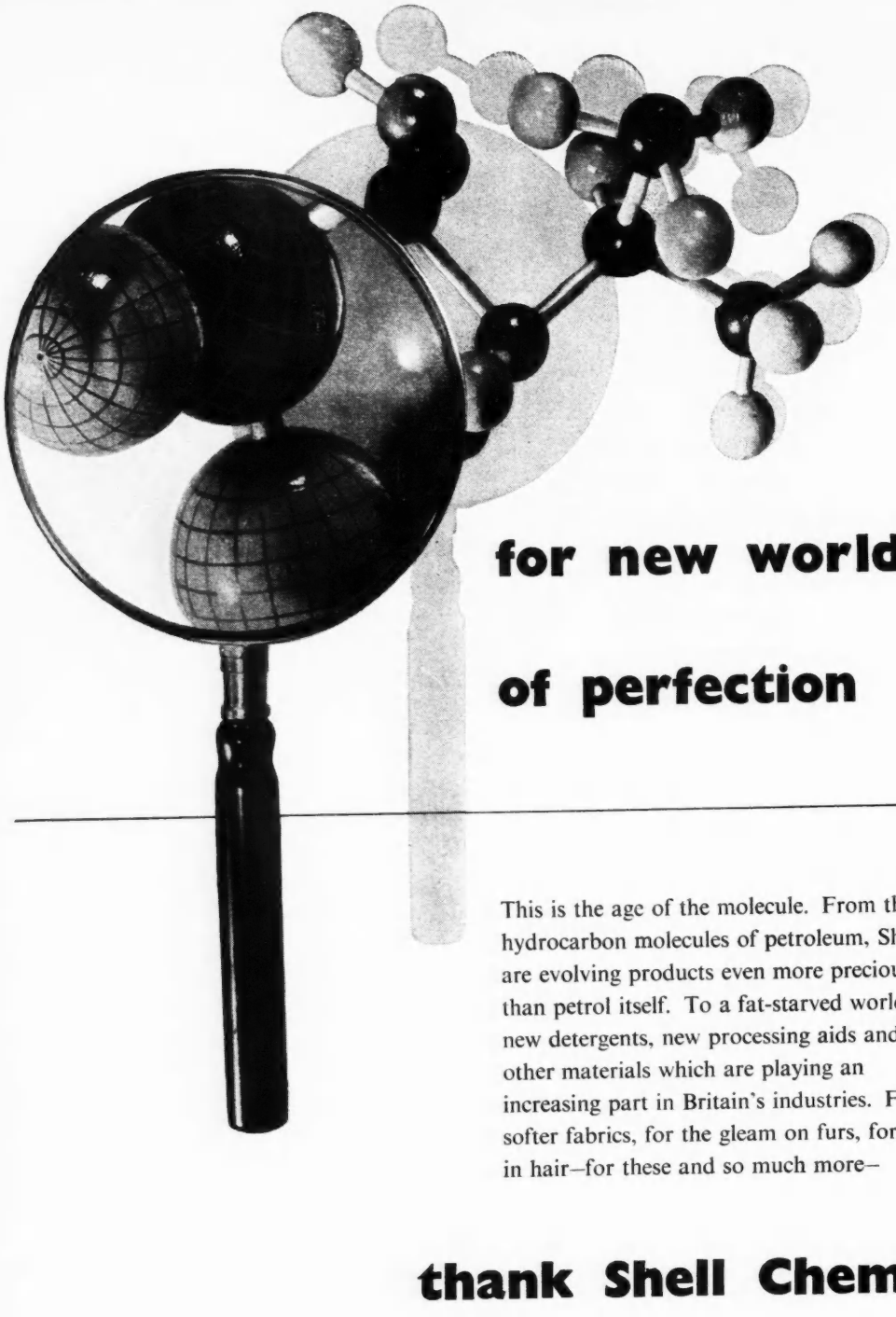

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DISCOVERY

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The Progress of Science

Why there was no German A-bomb

WHEN the allied forces invaded western Europe, a team of American scientists followed close behind the advance units, and indeed sometimes ahead of them. Known as the Alsos Mission (*alsos* is Greek for Groves, and General Groves was, of course, the Army chief of the U.S. atom bomb project), this team had the task of finding out what progress the Germans had made towards the atomic bomb. The story of how this was done, as told by Professor Samuel A. Goudsmit in *Alsos, the Failure of German Science* (London, Sigma Books, 1947, pp. 259, 15*s*.), reads like a well-constructed detective story. We see Goudsmit and his colleagues piecing together a picture of German nuclear research out of such clues as the lists of visitors found in the doorkeeper's book of a company dealing in rare chemicals, or a list of their registered mail, or odd documents and scraps that had been missed by the Germans when cleaning up prior to retreat.

Added to the detective story interest is a comedy-of-errors plot in the full Shakespearian style. For both Germany and the Allies had completely wrong ideas about the other's progress. Many of those who knew of atomic developments in America had studied at the feet of great German scientists 20 years before; naturally they assumed that German science was ahead of American. Otto Hahn's discovery of fission might have meant a two-year start for the Germans, and many American scientists seem to have assumed that the Germans in fact held a two-year lead. The quick rebuilding of the Norwegian heavy-water plant and the obvious German interest in Joliot-Curie's laboratory at Paris were thought to point in this direction.

At first the Alsos team found plenty to confirm this fear. In autumn 1944, they discovered that the chemical firm already mentioned had a monopoly of thorium and that just before D-Day the entire thorium stock had been moved to Germany. "This," says Goudsmit, "really scared us. Thorium, we knew, could be used in an A-bomb project, when that project was in a well-advanced stage. Did this interest in thorium mean that the Germans were really ahead of us? We checked carefully what industrial uses there might be for thorium, and had to conclude that even a small fraction of the stolen amount would last ordinary industry another twenty years." Eventually, the mission discovered that they had merely been deceived by what might have proved a slick piece of commercial exploitation—the company had ambitious post-war plans for selling a 'thoriated toothpaste'! (The author suggests this slogan: *Have sparkling brilliant teeth—radioactive brilliance*! and adds a sly comment, "After all, America had its Bob Hope and Irium toothpaste.")

It was not till after the occupation of Strasbourg in the middle of November 1944 that Alsos found odd scraps of documents containing enough information to show that the Germans had no atomic bomb and would not have one in any reasonable time. Letters from one scientist to another, odd scraps of calculations and the like combined together to show that the Germans had been unsuccessful in the separation of U-235, except on the most minute scale; they had only recently succeeded in manufacturing uranium metal; and their work on the pile had reached about the same stage as that which the Allies attained in 1940. At this point American misconceptions of German progress were banished.

But the German scientists remained deceived much longer. Confident of the superiority of German science to all other, they interpreted their own failure as proof that the Allies must have made even less progress. Thus Rudolph Mentzel, the scientific fourth-rater who was director of the Reich's Research Council, reported officially on July 8, 1943, "Though the work will not lead in a short time towards the production of practically useful engines or explosives, it gives on the other hand the certainty that in this field the enemy powers cannot have any surprise in store for us." Professor Werner Heisenberg, after his capture in 1945, made this magnanimous offer: "If American colleagues wish to learn about the uranium problem, I shall be glad to show them the results of our researches if they come to my laboratory." In February 1945, Gerlach believed that German nuclear knowledge was a secret of vital importance to the world, which his government could use as a bargaining weapon to secure easier peace terms. And Goudsmit draws a vivid picture of interned German physicists listening to the news of the

first bomb on Hiroshima; they could not bring themselves to accept the facts, and tried to dismiss them as mere propaganda.

In fact, the results the Germans had obtained were quite pitiable. Their efforts at isotope separation were very ineffective; they managed to get only one centrifuge working, but this would have taken a hundred years even to enrich the U-235 content sufficiently to make it easier to construct a pile. They had produced enough evidence to show that a self-sustaining pile was possible, but they were still a very long way from building one. In spite of a suggestion of the principle in a secret report, written by Fritz Houtermans in 1941, the leaders of German atomic research had not realised the possibility of producing plutonium in the pile and using this as an explosive. And since they did not believe isotope separation to be practicable, they were reduced to one possibility for the bomb —namely the idea that a large, fast-acting pile would be explosive (Fig. 2). That was their target, and when eventually they were convinced that an atomic bomb really had been dropped on Hiroshima they thought that the American planes had actually carried a complete pile there!

All this puts some subsequent German statements in a strange light; for instance, one made by Heisenberg to the Press in mid-1947: "Germany's uranium pile, which I was building up to create energy for machines and not for bombs. . . . As the world now knows, the explosive, plutonium, is produced in such a uranium pile." Professor Goudsmit's comment is that this "is a beautiful example of how to use half-truths". The Germans were working on a 'machine' and not a bomb, but that was at least partly because they did not appreciate the difference; and what 'all the world now knows' is very different from what German physicists knew before they were told after Hiroshima.

Germany's industrial difficulties under the strain of war and allied bombing would explain a failure to develop such projects as large-scale isotope separation. But they will not explain why that country was so backward on the purely scientific side. The immediate explanation of the last lies partly in such things as the miserably small scale of research and the lack of equipment (only one cyclotron was ready for use by the end of the war). But these cannot be put down entirely to lack of appreciation by the authorities—the scientists themselves were not sufficiently confident to push their case and not until 1942 did they begin to make any real effort to interest the military people. Again we can find partial explanations in the graft and incompetence which permeated the whole Nazi scientific organisation. This was reflected in the atomic work; from Goudsmit's book we find that at one time there were actually three separate atomic research projects in the Reich—one of them was organised by the research section of the Postal Department! For a long time there was no co-ordination at all between the three projects.

But all the more important reasons for the failure are closely related to the Nazi system and the Nazi ideology. The system required the appointment of ardent Nazis to all the higher posts, and from this stems the major part of the mis-direction of the effort. The expulsion of Jews meant a severe loss to German science. And more than that (as Dr. Thirring showed in a book which we discussed in DISCOVERY in August 1947), the anti-Jew mania led to the stigmatisation of certain sciences, particularly the more theoretical ones, as non-Aryan, with the result that a good Nazi could not even believe some of the fundamental theories on which nuclear energy work must be based. The whole Nazi ideology fostered obscurantism and superstition. In such an atmosphere really scientific methods would have little chance. Professor Goudsmit suggests that much of the failure resulted from a tendency to regard Heisenberg as *the* atomic authority and to believe that 'lesser' scientists could have nothing important to contribute. In this belief Heisenberg (whom Professor Goudsmit describes as "a man of ideals, but ideals distorted by extreme nationalism and a fanatical belief in his own mission for Germany") seems to have shared. Hence the way in which Houterman's ideas, which could have led to the concept of the plutonium bomb, were ignored. In all those ways it is clear that the failure of German atomic bomb research was a direct and necessary consequence of German fascism.

In some respects we see that the state to which the scientific life of Germany had been reduced was not far different from that which existed in countries which the Nazis occupied and pillaged, and whose culture the Nazis set out intentionally to destroy. There is poetic justice in this scientific Götterdämmerung, over which the Germans can expect no sympathy, for the greatest harm that has been done to the growth of German science has been done by the Germans themselves—by the Nazis and those who acquiesced with the Nazis. In addition there was considerable destruction of German laboratories by the Allies during the war, and after Germany's defeat a great deal of scientific equipment was rightly removed by the occupying powers, while many German scientists and technicians (mainly connected with military scientific developments) left the country to work abroad, in Britain, America and Russia. German science has gone through a very unhealthy period, and its immediate prospects are very far from bright. But there are signs that a revival of German science, and, what is even more important, of the better traditions that actuated German scientific efforts before the Nazis came to power, is under way. Key figures in this revival are the scientists who stayed in Germany and kept their integrity in spite of all the pressure the Nazis put upon them. One such man quoted in Goudsmit's book is Professor von Laue, and Professor Otto Hahn, discoverer of uranium fission, is another who would not compromise with the Nazis. It is good to find that Hahn is president of the Max Planck Society (recently formed with the approval of the British and American Military Governments), and that both Hahn and von Laue are *ex officio* members of the Council which directs the affairs of this society, whose primary objective is the

Professor Werner Heisenberg in his twenties won the Nobel Prize for Physics (1932), for his enunciation of the 'uncertainty principle'.

encouragement of fundamental research in Germany on peaceful lines. The Max Planck Society is intended to fill the gap left by the dissolution of the Kaiser Wilhelm Society which was too tainted by association with the Nazis for the occupying powers or the German scientists to tolerate its continuance. German science is being put back on the rails, and there is some guarantee that its future movement will be in the right direction in the fact that scientists who left Germany because of the Nazis are associated with this revival. It is a good sign, too, that the coverage of Unesco has been extended to include Germany, at least the western zones.

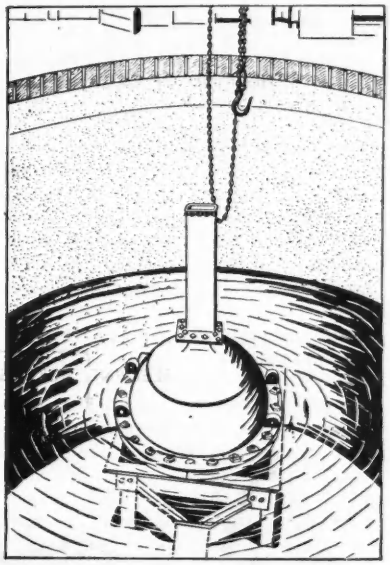
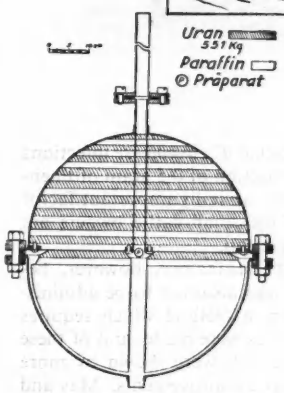


FIG. 2. GERMANY'S "ATOM BOMB"



(*Above*). Drawing of the German experimental 'uranium pile', which the German scientists believed would make an atomic bomb.
(*Left*). Diagram for the experimental 'bomb', which consisted of alternating layers of uranium and paraffin.

Phenanthridium 897

A SCIENTIFIC discovery has recently been announced which is likely to have a profound effect on the economy of Africa and other tropical and sub-tropical countries such as India and South America. In vast regions of these countries agriculture is dominated by an apparently insignificant insect, the tsetse fly. The importance of the tsetse fly is that it can harbour various species of protozoan parasites, known as trypanosomes, just as some species of mosquito harbour malaria parasites. The tsetse fly is a blood-sucking insect and thus may pass on the infection to men and animals. In men the infection becomes apparent as Sleeping Sickness; in cattle as Nagana. In both men and animals the mortality is high. Nagana disease is so severe that no cattle can economically be raised in the fly-belts. Trypanosomes can be spread also by ticks and lice. Thus Chagas disease, very prevalent in South and Central America, is another form of trypanosome infection.

The problem of the trypanosome-carrying tsetse fly is being tackled in many ways. These include destruction of the vegetation in which the flies breed and of wild animals, such as deer, which can also harbour the trypanosomes. Powerful insecticides, such as Gammexane and DDT, have been used in an attempt to eradicate the fly from large areas and to prevent it becoming re-established. To these can now be added a new series of drugs which have already proved very effective in treating cattle infected with two major species of trypanosomes.

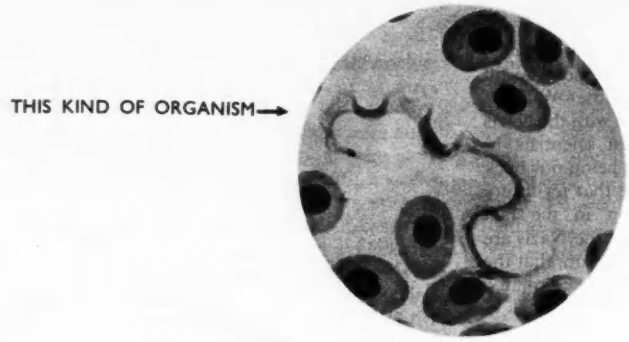
This research was initiated by Dr. L. P. Walls* at the Chemical Research Laboratory, Teddington. He later collaborated with Professor Browning, of the Department of Bacteriology at Glasgow. Dr. Walls decided to investigate the possibilities of preparing new chemotherapeutic agents from a substance known as phenanthridine, which, although easily obtainable, had hitherto received very little attention. This was no shot in the dark, for there seemed good reason to believe that phenanthridine derivatives might possess useful properties. Firstly, they include atomic arrangements identical with those found in quinine and pamaquine, the well-known antimalarial drugs. Second, phenanthridine is analogous to acridine and its derivatives, and the latter include such important substances as mepacrine, the main antimalarial drug used during the war, and acriflavine, which is a powerful antiseptic.

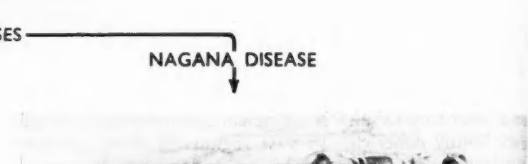
As a start simple phenanthridine analogues of well-known acriflavine antiseptics were made. Some of these were quickly found to possess antiseptic properties, a very promising start, which encouraged the more difficult task of preparing more precise equivalents of acriflavine drugs. Many hundreds of compounds were prepared and tested against various infective organisms, but not until Number 897 was reached was a substance obtained with really exceptional properties.

Phenanthridium 897 proved to be highly active against *Trypanosoma congolense*, the most important of the trypanosomes which infect cattle. At the same time its toxicity to animal cells appeared to be small. It thus fulfilled the two requirements essential for any successful chemotherapeutic agent; it was deadly to the infection, and apparently not dangerous to the body. Experiments with mice showed that it could be successfully used to combat *T. congolense* infections in these animals.

To test it against infections in cattle large quantities were prepared and sent to veterinary officers in tsetse fly areas of Kenya, Tanganyika, Uganda, and Nigeria. From the first three of these countries enthusiastic reports were received. Nigerian officials were less enthusiastic. In

*See Dr. Walls' paper, "The Chemotherapy of Phenanthridine Compounds", *Journal of the Society of Chemical Industry*, 1947, Vol. 66, p. 182.





general, however, it was found that *T. congolense* infections could be cured with a single injection of 0·5 gram of Phenanthridium 897. Furthermore—a vitally important factor in countries where many of the small cattle owners are desperately poor—the drug is cheap.

897 proved not altogether satisfactory, however, because it was somewhat toxic and also had to be administered by injection into a vein, a method which requires some skill. Yet more derivatives were made, and of these 1508 and 1553, especially the last, were shown by more field trials in Africa to be marked improvements. May and Baker Ltd. and Burroughs Wellcome and Company then supplied large quantities for more extensive tests, which confirmed the earlier results. The later tests did, however, sound a note of warning. It was found that the mice used in the laboratory responded to the drugs much better than cattle did in the field trials so that caution was needed in interpreting the laboratory results.

Yet another derivative—1544—has been found to be highly active against *T. cruzi*, the causative agent of Chagas disease, a scourge of South and Central America. The number 1544 is incidentally a reminder of the immense number of experiments which may lie behind the production of a single new drug. Before the war the German I.G. Farbenindustrie had gained much prestige in South America by sending a drug known as Bayer 7602 for combating Chagas disease. Experiments show that 1544 is at least as good.

(The photomicrograph showing a trypanosome—actually the species *Trypanosoma granulosum*—in blood is from R. M. Allen's *Photomicrography*, Van Nostrand, Chapman and Hall, 1941; magnification is about 1000 times. The other two pictures that illustrate this note come from *Fifty Years of Bayer Remedies*.)

Counting Diamonds

ONE of the essential tools of the nuclear physicist is an efficient and quick-acting device for counting the various types of radiation produced in nuclear changes. This applies both to gamma radiation, and to the counting of particles in the ordinary sense, particularly electrons. The time-honoured and still generally used device for this purpose is the Geiger-Müller counter which depends on the fact that a gas is rendered momentarily conducting by the various types of radiation which it will record. But useful as this instrument is, its counting rate is limited by the fact that it takes roughly one ten-thousandth of a second to recover after each discharge. Quick though this is by ordinary standards, it is slow compared with the rate at which counts can be added up and recorded, assuming that the initial responses can be separated. Hence the desire of physicists for a 'faster' type of counter (the radiochemist is less interested in 'speed') and recent interest in the possibilities of crystal counters for this purpose. Of these the diamond counter appears the most promising.

The story begins with the discovery by Sir Robert Robertson in 1934 that diamonds are of two kinds. While examining the opaqueness or otherwise of the diamonds to infra-red radiation, it was found by chance that one particular diamond was transparent to radiation of longer wavelength than the normal limit. Also, the same diamond was unusually transparent in the ultra-violet. Other properties were then investigated, and it was found in particular that there was a "marked photo-electric or photo-conductive effect", in contrast to the very feeble response to light shown by diamonds of the usual type. In other words, if one of these Type 2 diamonds—as they were called—was held between two electrodes, then the

impact of light radiation caused a measurable electric current to flow through the diamond. In some cases this happened even if no potential was applied across the diamond, in others a 'small' potential was needed. But no attempt was made to observe the effects of gamma radiation.

Then in 1945 P. J. Van Heerden, at Utrecht, made the first serious investigation of crystals as radiation counters. He was most successful with silver chloride crystals. But to obtain a measurable effect he had to work at the temperature of liquid air, and his experiments with diamonds were a failure. This, as is now clear, was because he did not test a large enough number to include any of the Type 2 variety which Sir Robert Robertson had discovered.

The first positive results with diamonds were obtained last year by E. D. Wooldridge, A. J. Ahearn and J. A. Burton in the Bell Telephone Laboratories. They used diamonds to count alpha particles, reported no indication that Type 2 diamonds were necessary, and pointed out that their results immediately suggested the use of the diamond "as a solid counter for nuclear physics experiments". The suggestion was quickly followed up by L. F. Curtis and B. W. Brown, of the National Bureau of Standards, for the 'counting' of gamma radiation. They found that only a small proportion of diamonds could be used, and noted that all their successful counting diamonds were free from visible flaws and also were colourless. It was left to H. Friedman, L. S. Birks and H. P. Gauvin of the Naval Research Laboratory in Washington to complete the story by pointing out that the real criterion for success was that the diamond should be of the Type 2 variety. There are no exact figures for the proportion of diamonds which are of this kind, but after his first chance discovery Sir Robert Robertson had to examine about another hundred before he found a second specimen.

The Bureau of Standards instrument (Fig. 4) consists merely of a natural diamond held in a simple screw clamp, across which a high voltage (of unstated figure) is applied. Exposure to radiation causes a pulse of current to flow across the diamond, and this pulse is then amplified. In their 'best' counting diamond, the amplitude of the largest pulses was roughly ten times that of the 'background noise' due to the combined effects of the diamond and the amplifier. One may imagine that the impact of the original radiation or particle knocks out a single electron from one of the atoms of the diamond lattice. This is then attracted towards the positive terminal and is accelerated as it moves towards it. On the way, it hits other atoms, and knocks further electrons from them, so that by the time the electrode is reached enough electrons have been released to produce a measurable pulse. Preliminary trials, as already indicated, were with gamma radiation. But the suggestion is that the instrument could also be used for the counting of electrons, and that the diamond is 'fast' compared with the Geiger counter. As against this, sensitivity clearly varies considerably from one diamond to another.

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Science and Painting

A NOTABLE event occurred a month or so ago when a scientific body—the Colour Group of the Physical Society—met within the portals of the National Gallery. The subject under discussion—the cleaning of pictures—was one which has been the cause of much heated controversy amongst artists, critics and laymen, but on this occasion all was peaceful. The only criticisms voiced were concerned with the method of illuminating the gallery, and not with the results of the cleaning processes. However, the technical problems involved in cleaning pictures are of such interest that no apology need be made for recounting some of them here.

Why does a picture need cleaning? There are two main reasons. In the smoky atmosphere of a city a large amount of plain dirt accumulates over a period of years, obscuring the paint with a grey film. Secondly, chemical and physical changes take place in the layer of varnish with which the surface is 'protected'. These changes, besides affecting its mechanical properties, result in a yellowing and darkening of the film. At the time of application most of the varnishes used on old paintings were clear liquids, absorbing very little visible light, but having a strong absorption for the near ultra-violet. As time goes on this ultra-violet absorption gradually extends across the visible spectrum, absorbing first the violet, then blue, and eventually some of the green rays. The colours of the painting, besides being dulled by the dirt, are affected in different ways by the yellowed varnish. Blues become black and blue greens become darker greens. Greens may become yellowish, but yellows, oranges and reds are practically unaffected. Purples and mauves become reds and browns. The whole balance of the colours in a painting is seriously distorted.

It needs to be recognised that the *primary* reason for removing varnish arises from the contraction that occurs in aging varnish. When the contractile force exerted on the paint below becomes strong enough, the paint begins to be pulled away in flakes. At this stage the varnish must be taken off, otherwise disintegration of the painting will follow inevitably.

Fortunately it is nearly always possible to find a solvent, or mixture of solvents, which will dissolve the varnish without affecting the oil of the paint beneath, and it is this fact which makes cleaning possible. Each picture must be investigated individually, and tests are made on portions of the margin obscured by the frame to determine the appropriate solvent. It may even be necessary to use a different solvent for different parts of the same picture.

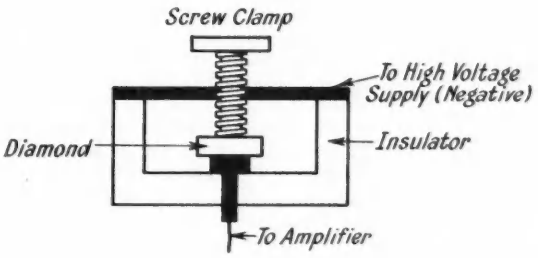
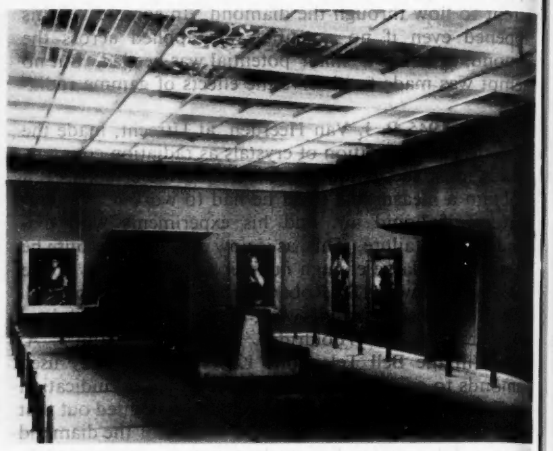


FIG. 4.—The Bureau of Standards counter.



FIGS. 5 and 6.—A model showing what may be a great advance in the natural lighting of picture galleries was seen at the annual exhibition of scientific instruments and apparatus of the Physical Society Exhibition last month. The model was designed by the Building Research Station, to show how the war-damaged rooms at the National Gallery might be reconstructed. It is difficult to daylight large picture galleries well, and at the request of the Ministry of Works, the Building Research Station has made a study of the problem.

The essential feature of the model is a louvre system arranged so that the strongest light falls on the paintings—not on the upper parts of the walls—and so that no direct view of sky is obtained from the main part of the floor. The louvres cut down the amount of light entering the room, but they produce much better conditions for seeing the paintings. Another feature is a glass louvre system *outside* to help to protect against the heat of the summer sun. Studies have shown what types of diffusing glass are most suitable for the louvres. A third idea is the hood over each door, so that a visitor entering the room does not get a sudden view of sky direct in the eyes.

FIG. 5 (*left*).—General view of model. The top portion is on the ground, and the louvres, and the daylight (this comes below the louvres and reduces the amount of air that has to be air-conditioned), have been lifted. FIG. 6 (*right*)—View of interior of model.

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Much still depends on the skill of the cleaner, but he now has many scientific aids on which to base his diagnosis and treatment.

The cleaning of a picture is seldom simply a matter of removing the dirt and revarnishing. Blemishes such as cracks in the paint film, blisters or accidental damage are found and require restoration. This is nowadays carried out in water-colour or some other medium which can be easily removed at a subsequent cleaning. Much of this damage, it is now known, is caused by the continuous variations in the atmospheric conditions in which the pictures are kept, and it can be minimised by suitable air conditioning. A painting, to the physicist, is an inhomogeneous body composed of a support, which may be wood or canvas, several layers of pigment and a layer of varnish. Until it is a year or two old the outer layers are relatively soft and plastic. Changes in dimensions of the support can be followed without strain. Gradually these outer layers harden and become rigid, and it is an astonishing fact that this rigidity is sometimes great enough to prevent the natural swelling and shrinking of the support which normally accompanies changes in the humidity of the atmosphere. Eventually, however, the strain becomes too great and the paint film suddenly cracks. It is welcome news, therefore, that parts of the National Gallery are soon to have an air conditioning system which will maintain a constant humidity and temperature.

Having removed the obscuring layers of dirt and discoloured varnish from a painting, it is, of course, important that the illumination in which it is hung should do justice to the colours revealed. The sensation of colour perceived by the eye depends as much on the spectral composition of the light falling on the pigment as on the pigment itself. No one, for example, would dream of exhibiting pictures under the mercury discharge lamps used for street lighting. It was, therefore, surprising to many members of the Colour Group to find that both 'Warm-white' and 'Daylight' fluorescent lamps had been used to illuminate the cleaned pictures. These light sources are seriously deficient in deep red radiation, with the result that certain red pigments appear duller than in daylight. Distortions may also occur in the deep blues and violets owing to the strong mercury lines in this part of the spectrum. Normal tungsten filament lamps, with their preponderance of red and yellow rays, also distort the colour values of a painting seriously, but we believe that the problem of artificial illuminants for picture galleries is not insuperable. We understand that this problem is receiving the attention of the scientists on the staff of the National Gallery, and that an improved system of lighting will be introduced as soon as practicable.

The proper distribution of the illumination is also of great importance since the comfort of the viewer is strongly affected by glare, bright reflections and other factors. The Building Research Station has been experimenting with a model (exhibited at The Physical Society's Exhibition this year) of a proposed reconstruction of a damaged wing of the National Gallery, in order to obtain the best distribution of daylight. Light from the sky is directed preferentially on to the pictures, while a direct view of the sky, with its distractingly high brightness, is prevented.

FIG. 1.—Producing synthetic sapphires in oxy-hydrogen furnaces. The operator, wearing dark glasses and looking through observation slits in the furnaces, can watch the growth of the synthetic crystals or boules.

Synthetic Minerals

W. A. WOOSTER, M.A., Ph.D., F.Inst.P.

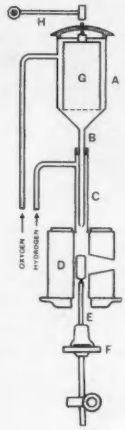
It was a great advance in human evolution when man adopted metal as the raw material for his tools and weapons in place of stone. Doubtless there were grousers who disapproved of these new-fangled bronze axes and knives, and maintained that there was nothing like flint, and what had been good enough for their fathers was good enough for them. And probably the champions of the new tools imagined that stones were a thing of the past. For a time metal was synonymous with progress, and for many centuries stones were used only for grinding cereals. When iron replaced bronze, however, the problem of sharpening the edge restored to stones some of their earlier importance. Today for many purposes stones outstrip metals in their performance, and modern industry is largely dependent on a wide variety of them.

With the exception of diamond and quartz, most of these stones are synthetic. Some of them occur in nature but in too small a quantity or in too poor quality to be of much use. Some differ from naturally occurring products because the synthesis of the natural stones may prove more difficult than a similar artificial product of analogous composition. Some are entirely human products, based on a knowledge of the fundamental relations between structure and properties.

The synthesis of minerals began in the nineteenth century. Most of the work was done in France where it happened that a majority of the chairs of mineralogy were filled by chemists. These men, seeking to unravel the problems set by the constitution of the earth's surface, synthesised a great variety of well-known minerals, but provided they were able to get crystals large enough to identify under a microscope they were content.

Naturally many people have tried to synthesise diamonds. It is doubtful whether their synthesis has been achieved by more than one man. In 1880 Hannay heated lithium, bone oil and paraffin in a welded iron tube to a red heat. In a few of his many experiments he obtained genuine diamonds, their identity being established by Story-Maskelyne, the Keeper of Minerals in the British Museum (Fig. 7). Hannay was not generally accorded the credit due to him, however, and in 1918 Sir Charles Parsons claimed to have repeated Hannay's experiments without success. In fact, Sir Charles's experiments differed from Hannay's in several material particulars, so that his conclusion (quoted in his biography published in 1933) "that no-one had ever made a diamond" would seem to be unjustified. Hannay's reputation has been restored, however, by an X-ray examination of the fragments that remained in Story-Maskelyne's possession. They were proved to be genuine diamonds.

Other attempts to synthesise diamonds have been made. Some pink diamonds, alleged to be synthetic, were examined and reported upon by some reputable mineralogists in Vienna before the last war. But the process by which they were made, if they were made, has been kept secret. Professor P. W. Bridgman, of Harvard, has more than once tried the effect of subjecting carbon to extremely high pressures, but he has obtained no encouraging



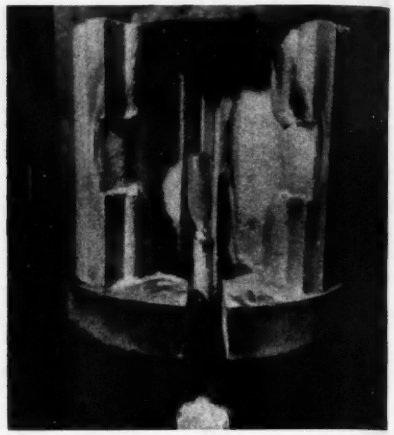


FIG. 2 (*left*).—The synthetic sapphires are produced from powdered aluminium oxide. A canister filled with the powder is being inserted at the top of one furnace.

FIG. 3 (*centre*).—Diagram of a Verneuil boule furnace. The canister G contains aluminium oxide powder. To start the process the oxy-hydrogen burner is lighted and the small hammer H is set in motion, to tap down the powder at a slow and regular rate. As it falls through the flame the aluminium oxide is melted; the molten particles settle on the refractory candle E (which can be raised or lowered by a handwheel) and build up stalagmite-fashion into a synthetic sapphire crystal. (*From the G.E.C. Journal.*)

FIG. 4 (*right*).—A fully grown crystal on its refactory candle.

results. Reports in newspapers alleged that diamonds were produced when the first atomic bomb was released, but if such diamonds exist, they have suffered the same secrecy imposed upon certain other atomic work.

The diamond has been used for cutting hard materials since biblical times. When crushed to a powder, it forms the most effective abrasive known. As a turning tool, if properly made and properly used, it can produce a surface that is unequalled for smoothness of finish.

Artificial Abrasives

Diamond tools, however, are expensive and because diamonds are brittle they do not make suitable tools for heavy turning work. Tungsten carbide and boron nitride are largely used for such purposes, particularly for dealing with hardened steels, armour plate and the like. These substances and other hard abrasives such as carborundum (which is prepared by heating together sand, coke, sawdust and salt, to 1800°–2000° C. in an electric furnace) are bonded together in the form of grinding wheels and discs. These tools are not only extremely hard, but tough as well.

Another hard substance of great practical importance is corundum, crystallised alumina. This occurs in nature, and when coloured red through the presence of a small quantity of chromium, is known as ruby; the blue or yellow stones are called sapphires. In addition to their use as jewels they are valued as bearings, and they were employed for this purpose, in spite of their high price, when chronometers of the highest quality were called for.

Rubies and sapphires have been synthesised with outstanding success. Originally the process was developed to make gemstones. Large, practically flawless stones of brilliant colour were produced, which passed all the criteria normally considered to test the genuineness of a stone. For a while they fetched extravagantly high prices, but so many of these fine stones found their way to the market that their artificial origin was soon apparent. The place where they were proved to be made was Switzerland. The bottom then dropped out of the whole ruby market, until it was discovered that certain small bubbles, present in both natural and artificial stones, have a random distribution in the former and a regular distribution in the latter. The price of natural rubies then went back to its former value.

The Verneuil Process

Though the price of artificial stones fell catastrophically, the process which was developed and patented by Verneuil in 1902 proved extremely valuable for producing colourless corundum for the mass production of bearings, particularly for watches and clocks. (Figs. 1–6.) Briefly the process is as follows: Finely powdered aluminium oxide is supported in a funnel-shaped vessel from which it can be tapped down at a slow and regular rate. As it emerges from the funnel it enters an oxy-hydrogen flame in which it is heated to about 2000° C. so that it melts. The molten particles descend through the flame and settle on a white-hot surface of corundum. In the initial stages of a run a seed crystal is used which is heated up to the proper temperature before the powder is tapped from the funnel. The molten corundum rapidly crystallises on cooling, which is brought about by slowly lowering the seed crystal by means of a clockwork mechanism. The level of the top surface is maintained at the same height in the flame. The rate at which the boule, as the artificial crystal is called, can be withdrawn, depends upon the diameter of the crystal being grown. If it is withdrawn too fast,

FIG. 5.—A sharp blow splits the boule into roughly symmetrical halves.

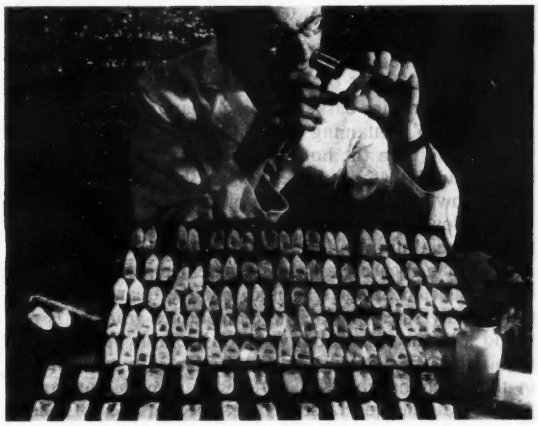


FIG. 6.—The boules are inspected before they are cut into jewels.

instead of a single crystal resulting there are a number of more or less parallel narrower crystals. Narrower crystals can be grown at a greater rate than wider ones; with narrow crystals as much as 300 carats* may be produced in five hours. During the war narrow rods—knitting needle boules—of the right diameter for cutting up into bearings were produced, but unfortunately the least satisfactory direction for a bearing surface had to be utilised, so that only inferior products could be made from these. The length of boule that is produced depends only on the design of the withdrawing mechanism; boules can be feet long, though as a rule they are only a few inches. The knitting needle boules do not split down their lengths, but larger boules either spontaneously or when tapped invariably do. They are cut up and shaped into bearings by grinding with diamond powder, a relatively expensive process. In Germany during the war this presented a serious problem, because diamond powder was in very short supply. This led to the development of an alternative material being used for the bearings.

Instead of pure alumina a mixture of alumina and magnesia was employed, forming boules of spinel. These were similar to those of corundum, but they showed a greater tendency to develop crystalline faces on the sides. The hardness of spinel is normally much less than that of corundum, so that shaping the crystals into bearings took appreciably less diamond powder. But it was found that if the proportions of alumina and magnesia were suitably adjusted the bearings could be treated after manufacture and their hardness raised, even beyond that of corundum. The causes of the hardening are essentially the same as those that operate in the hardening of certain metallic alloys. If the magnesia is in excess there is a tendency for the magnesia to separate out of the spinel as magnesium oxide crystals, if the bearing is kept at a suitable temperature. This raises the hardness a great deal. Spinel practically replaced corundum as a bearing material in Germany as a result of this discovery.

Another mineral synthesis of considerable economic and scientific importance was also developed in Germany during the recent war. This was the synthesis of high-quality mica crystals, some up to 6 inches across. The artificial mica differed from natural mica in that the hydroxyl radicle in the latter was replaced by fluorine. It was prepared by heating together alumina, magnesia, silica and potassium silico-fluoride. These materials were prepared by grinding together and compressing into tablets which were then heated to melting, occurring at about 1450° C. Thereafter the cooling was carefully controlled so as to start crystallisation at the bottom of the crucible and to allow it to proceed upwards at a pre-determined rate. Too rapid a rate of cooling resulted in smaller crystals. The crystals obtained by this process were set vertically in the crucible. Some work using magnetic fields showed that if a magnetic field was applied in a horizontal direction the crystals all grew with their planes perpendicular to the field. This process is important because in addition to the technical value of the product, an interesting field of synthetic micas with unusual properties has been opened up. Mica is of particular value in making electrical condensers.

Another crystal that is important because of its electrical properties is quartz, which exhibits the property of piezoelectricity. If quartz is distorted in a suitable way with respect to its crystallographic axes, it develops electric charges on its surface. In reverse, if electric charges are imposed there is an equivalent distortion. This property is made use of to an enormous extent in the radio industry and telephone industry for the control of frequency. During the war thousands of tons of quartz were cut up into oscillator plates.

Growing Quartz Crystals

Only quartz of first-rate quality can be used for this purpose. Such quartz is found in large quantities only in Brazil and the U.S.S.R. Consequently there has been great interest in its synthesis. This has been achieved by many people and by many methods, but mostly with the production of crystals too small to be useful. The first experimenter who produced a large crystal of quartz was an

* 1 carat = 0·2 gram.

Italian geologist, Spezia, who in the early years of this century grew a crystal a centimetre across on a seed crystal. His method was to suspend a quartz seed in an aqueous solution of sodium metasilicate and salt underneath a silver wire basket holding quartz chips. The top of the 'bomb' containing the solution was held at a higher temperature than the bottom, so a temperature gradient, and a solubility gradient, were established inside. This led to the growth of the seed, but the process, though successful, was so slow—a centimetre requiring five months—that as a commercial proposition it holds out little hope.

In England a process has been patented in which a solution similar to Spezia's is used, but the quartz chips are replaced by silica glass. The temperature gradient is not found to be necessary, but very considerable pressures are required. After holding the container at a temperature in the neighbourhood of 400° C. for several hours, it is found that the quartz seed has added a layer of quartz to itself. This can be cut off and used as an oscillator, and the seed used again.

An attempt was made in Germany to synthesise nepheline ($NaAlSiO_4$), which is another piezoelectric mineral. The components were heated with lithium fluoride in an open crucible and after a suitable interval were allowed to cool down. Plate-like crystals were formed, up to 5 millimetres across. Their piezoelectric properties have not been investigated.

Another group of substances which are valuable for their piezoelectric properties are water-soluble, and crystals of these substances may be grown from saturated or supersaturated solutions. Rochelle salt is one of these. In many respects it is much more powerful than quartz, but it lacks its admirable mechanical qualities. Indeed, it is difficult to cut it up without damage, a disadvantage that has been overcome by an ingenious modification of the growing technique. A suitable seed is accurately orientated between parallel glass plates, so that the orientation required is obtained by the simple device of mechanical restriction.

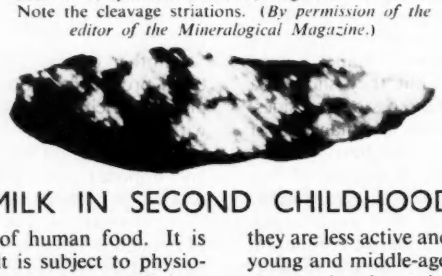
A further important field that has been invaded by synthetic crystals is that of optical prisms and lenses, particularly for use in the infra-red and ultra-violet regions. In this field man has far outstripped nature in the size and perfection of the crystals grown. The method is essentially similar to that described for mica, except that the whole crucible is occupied by a single crystal at the end of the run. Sodium and potassium chlorides, sodium and potassium bromides, lithium fluoride and potassium iodide, silver chloride and thallium salts are among those that have been grown for such purposes. There is no reason to suppose that other substances will not respond to similar treatment. Probably no other single factor than the provision of such optical materials has helped more in the development of our knowledge of the non-visible regions of the spectrum.

Brief mention may be made of the barium and strontium titanates which have remarkable dielectric properties and may be expected to have interesting piezoelectric properties if they can be produced in good single crystals; and of the many artificial refractory materials and glasses that have resulted from scientific studies; also of artificial gems. The rubies and sapphires already described are the most valuable of these, since they can be produced in a great variety of beautiful colours, and have the hardness that a satisfactory gemstone requires. The spinels are also used, particularly in Germany in recent times. Synthetic emerald has also been made, both in Germany and in America, but the method has been kept a secret.

It is by no means impossible that in the future gems which have no counterpart in nature may be produced, just as other new minerals have been synthesised, for the principles of crystallisation, the possible combination and substitution of the elements and the physical properties that may be expected to result are now reasonably well understood.

(The photographs illustrating this article were taken at the G.E.C. factory at Salford, where production of synthetic sapphires was commenced at the beginning of the recent war, after Swiss supplies had been cut.)

FIG. 7.—A synthetic diamond, magnified 130 times. Note the cleavage striations. (*By permission of the editor of the Mineralogical Magazine.*)



MILK IN SECOND CHILDHOOD

Cows' milk is a valuable source of human food. It is particularly valuable when an adult is subject to physiological strain such as pregnancy or nursing and it is a necessity for growing children. Its value is due firstly to its high content of calcium and phosphorus, which are essential for bone growth, and secondly to its content of first-class protein which has a high biological value.

Normal adults seem to benefit from the consumption of milk—probably because it supplements some dietary constituent in which their food is inadequate. Experimental evidence is accumulating which shows that elderly people would also benefit from extra milk. It has been the custom to say that old people need less food than normal because they are less active and their metabolic rates are lower than young and middle-aged adults. However, their ability to absorb vitamins, minerals and so on from their food is often greatly impaired so that in fact they need at least as much, if not more, nutritious food than younger people. Elderly people often suffer from demineralisation of the bones which results in them becoming fragile and liable to easy fracture. K. M. Henry & G. K. Kon (*Biochemical Journal*, 1947, Vol. 41, p. 169) have found that this progressive demineralisation of bones in old age can be prevented in experimental animals by increasing the amount of calcium and phosphorus in the diet. It is very likely that the same results could be obtained with human beings.

Rh Blood will tell

HELEN CLAIRE HOWES

If you have ever been a blood donor, you are probably aware that there are four major groups of human blood—A, B, AB and O. Although these differences were recognised in 1900, blood transfusion did not become accepted medical procedure until the World War I. It was well known by then that if group A blood were transfused into a patient with group B blood (or vice versa), some antagonistic substance in each would destroy the red blood cells of the other. A violent reaction, and possibly death, would follow. Group O 'universal' blood seemed the only safe type to give to persons with one of the other three, and only the person in AB group was able to receive A, B, or O in safety.

But even when physicians obeyed all the existing rules, transfusion reactions still occurred, particularly in patients previously transfused. Also, obstetricians continued to worry about those stillborn babies, the deeply jaundiced, and the pale little mites who developed jaundice and died, apparently without cause. Strangely enough, such tragedies happened more often to mothers who had had a previous difficult birth, an abortion or transfusion. In most of these cases, there was destruction of the red blood cells in the newborn child. The term, *erythroblastosis fœtalis*, was used to describe this type of anaemia. The cause of this condition, and also of certain transfusion reactions, remained a mystery until discoveries were made which partly explained certain differences in human blood.

The Rhesus Factor

Around 1940, experiments proved that when blood from the common rhesus monkey is injected into a rabbit, it acts as a foreign substance against which the rabbit builds up resistance. This resistance is in the form of antibodies which develop in the blood serum—fighters ready to ward off a second attack from the invader. When a sample of the rabbit's serum, containing the antibodies, was mixed with the monkey blood in a test tube, the antibodies reacted with the red cells of the monkey's blood. The rabbit's antibodies acted 'anti-Rhesus'. That factor (antigen) in the monkey's blood cells, which caused the rabbit to produce those antibodies, was called the Rhesus or Rh factor. The monkeys were said to be Rh positive.

It was later found that such antibodies would react with the red cells of 85 % of white people who, having this Rh factor in their blood cells, were called Rh positive. The remaining 15% who did not have it were called Rh negative.

Moreover, antibodies similar to those in the injected rabbit were found in the blood serum of some men and women who had suffered transfusion reactions, and also in mothers whose babies had erythroblastosis. These men and women were found to be Rh negative. In the cases of transfusion reaction, blood serum containing the antibodies clumped and destroyed the blood of the transfusion donors. In addition, the serum of the mothers reacted with the blood of their affected infants and, usually, with that of the fathers of these infants. The blood donors, the erythroblastic infants and the fathers in these cases were all found to be Rh positive. Thus it was proven beyond doubt that differences in Rh status can be responsible for transfusion accidents as well as for erythroblastosis.

Tests done since on large numbers of people have shown that approximately 87% of the white race and almost 100% of the Mongolian and Negro races have the Rh factor in their red blood cells. The remainder lack it. The blood of every human, therefore, can be categorised as A, B, AB or O, and each, in addition, is either Rh positive or Rh negative. There are many Rh subtypes (and other distinguishing factors in blood, known as M, N, and P), but they have no practical importance in this article.

Further investigation since the original discovery has shown that the presence of the Rh factor is an inherited characteristic upon which nationality, religion, sex or social status of an individual have no influence. Every human being possesses two genes which determine his Rh status, one inherited from each parent; this permits of three combinations: two Rh positive genes, or two Rh negative genes, or one of each. A person having similar Rh genes is called 'homozygous'. A person with one positive and one negative is referred to as 'heterozygous'; this individual tests as Rh positive but is able to transmit either a positive or a negative gene. This body of information comprises a very useful tool in anthropological studies and may be recognised in some courts of law for identification and for the exclusion of paternity.

"This is all very interesting," you will ask, "but how does the Rh factor concern me?" Not very much if you are

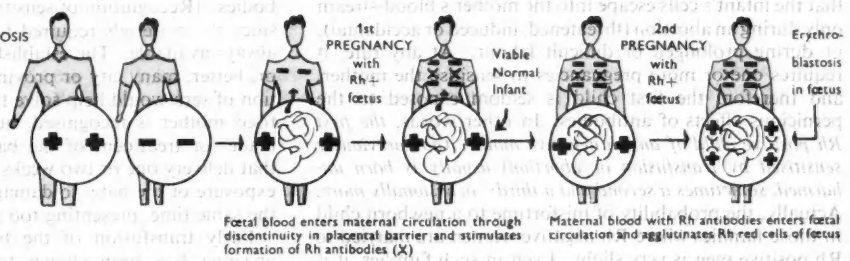


Fig. 1

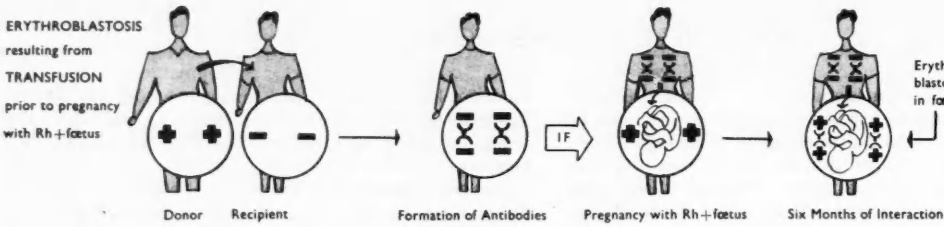


Fig. 2

Rh positive since your chances of falling foul of the Rh factor are slight. It matters very much, however, to every Rh negative male *and* female who is about to be transfused, especially if more than one transfusion is anticipated, and today that is always a possibility. Should an Rh negative person be transfused with Rh positive blood, he may react against the Rh factor and build up antibodies. These, once developed, will remain in the body permanently. The person is then said to be 'sensitised' or 'immunised' against the Rh factor. Sensitisation occurs more easily in some persons than in others. It has been determined that 40% to 50% of Rh negative persons will become sensitised to the Rh factor by transfusion. Should a further Rh positive transfusion then be given to this Rh negative patient, his antibodies will destroy the Rh positive cells just introduced. A severe reaction may follow and, to say the least, it will do the patient little good. The all-important thing to remember is—*if transfusion calamities are to be avoided, only Rh negative blood must be given to Rh negative persons.* This rule should be observed without exception, even though Rh negative donors are sometimes difficult to procure. Plasma, though not always an adequate substitute for whole blood, fortunately does not cause sensitisation to Rh.

The next important aspect of the Rh problem is that of pregnancy. As in transfusion, the Rh positive woman has little to fear. A small percentage (about 5%) of Rh negative women, however, *can be sensitised by a pregnancy* in which the child is Rh positive, the positive factor being inherited from the Rh positive father. On very rare occasions, sensitisation may occur even though mother and baby are both Rh positive, but of different Rh subtypes. These cases are so infrequent that we need not consider them here.

It is thought that the Rh positive fœtus sensitises the Rh negative mother through the escape of Rh positive cells from its circulation into the maternal circulation where they cause the development of antibodies. Some believe that the infant's cells escape into the mother's blood-stream only during an abortion (threatened, induced or accidental), or during prolonged or difficult labour. At any rate, it requires one or more pregnancies to sensitise the mother, and therefore the first child is seldom exposed to the pernicious effects of antibodies. In other words, *the first Rh positive child of an Rh negative mother (not previously sensitised by transfusion or abortion) usually is born unharmed, sometimes a second and a third—occasionally more.* Actually, the probability of misfortune to a newborn child in those families where Rh negative women are married to Rh positive men is very slight. Even in such families, it is common to have from one to three normal children before the disease makes its appearance. See Fig. 1.

In the small minority, however, in whom sensitisation does occur, the antibodies produced by the Rh negative mother (in response to the Rh positive cells of the fœtus) will return through the placenta in that pregnancy, or a subsequent pregnancy, to destroy the red blood cells of the fœtus. This destruction commences before the birth of the baby so that at birth the child may suffer from anaemia. The manifestations of this condition, erythroblastosis (or haemolytic disease of the newborn, as it is now called), are extremely varied. In some cases there is simple anaemia which may not be apparent for several days after birth. In other cases there is extreme blood destruction evidenced by jaundice or even death of the infant. The liver, spleen and nervous system may be severely damaged, and a small proportion of those infants who survive may have some permanent defect.

One of the saddest results of Rh incompatibility is the birth of a diseased or dead child from the first pregnancy of an Rh negative woman who had been sensitised to the Rh factor by transfusion shortly before, or many years prior to, marriage to her Rh positive husband. See Fig. 2.

An even more tragic accident is the case of the Rh negative mother who, sensitised by the Rh positive fœtus, is transfused with Rh positive blood which causes severe reaction or death. See Fig. 3.

Transfusion at Birth

There has been no way devised to prevent an Rh positive fœtus from sensitising its Rh negative mother, nor the mother's antibodies from complicating subsequent pregnancies. Fortunately, however, the recognition of Rh sensitisation in pregnancy has become possible through the routine testing of Rh negative pregnant women for antibodies. (Recognition of sensitisation is sometimes difficult since the materials required for such recognition are not always available. The establishment of a national centre or, better, many city or provincial centres for the production of sera would help solve this problem.) Once a sensitised mother is recognised, however, preparation can be made for treatment of the baby at birth. It is believed that delivery one or two weeks before term may reduce the exposure of the baby to damage by antibodies without, at the same time, presenting too great a risk of prematurity.

Early transfusion of the baby to combat a possible anaemia has been shown to be effective in reducing

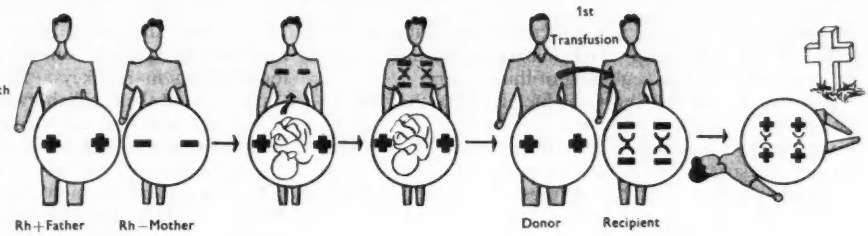


Fig. 3 Reaction to TRANSFUSION with Rh+blood after PREGNANCY with Rh+fœtus

mortality in these conditions. Successive transfusions, or replacement transfusion (exsanguination), in which the damaged blood is replaced by whole normal Rh negative blood from a non-sensitised donor, have given excellent results in some cases. Transfusion is most easily effected immediately after birth by utilising the veins in the umbilical cord. Although immediate transfusion is not considered a certain cure, such procedures have succeeded in saving the lives of many anaemic babies who otherwise would not have survived.

Once sensitisation has been established in a family and one or two affected children have been born, the outlook for future pregnancies is dubious since there is a tendency for haemolytic disease of the newborn to increase in severity with each successive affected pregnancy. It is important to decide in such families whether or not there is a possibility of a pregnancy being Rh negative and therefore, of course, not susceptible to damage by the mother's antibodies. This possibility will depend entirely upon the Rh constitution of the father. If he is heterozygous, i.e. possessing one Rh positive and one Rh negative characteristic, there is an equal chance in each pregnancy that the child will be Rh negative or Rh positive. This fifty-fifty gamble well warrants a trial.

If, on the other hand, he is homozygous, i.e. double Rh positive, all offspring will be Rh positive and, after the disease has appeared, all will be affected. In this case, if the parents do not wish to take the risk of having more erythroblastic babies, they must acquire the remainder of their family by other means, the most usual of which is by adoption. In some centres, artificial insemination of the sensitised Rh negative mother with spermatozoa from a proven Rh negative donor (with the full understanding and permission of the husband) has provided the couple with an unaffected child. It must be remembered that, *in cases where both mother and father are Rh negative, sensitisation through pregnancy is not possible as all children will be Rh negative.*

One evening some young wives were discussing this frightening possibility, haemolytic disease of the newborn. One mother of a six-year-old confessed that she had wanted several children but "the doctor said I was Rh negative and shouldn't have any more". Granted that the doctor gave her that impression six years ago, it would be well worth reviewing the situation today. The chances of her having a healthy child now are all in her favour. Statistics show that, although 13% to 15% of all marriages are between Rh negative women and Rh positive men, only one baby in twenty born to such couples has the disease. And, of all babies born, only one in 150 to 200 is affected.

There are many records of cases which terminated happily. Mrs. I.H. was a pregnant Rh negative wife who had had a healthy child in 1938. In 1939 another was born; it was jaundiced but survived. The third child was healthy, but the fourth and fifth were jaundiced and died. She feared that this child, too, would die. The whole family was blood-typed and the father found to be Rh positive, heterozygous. The first two children, who survived, were also Rh positive. The fourth and fifth, who died, were undoubtedly Rh positive. The third was Rh negative and therefore normal. When the sixth was born, it, too, was Rh negative and healthy.

Mrs. H.F. was pregnant again after having had three diseased or stillborn babies. She was found to be Rh negative with antibodies present which had developed, without doubt, following a transfusion after tonsillectomy at the age of six. It was decided to terminate pregnancy at the thirty-fifth week. A live child was delivered, transfused immediately and again later; it recovered completely.

To sum up—people have Rh positive or Rh negative type blood; the vast majority have the former. It is possible for Rh negative persons to be sensitised to the Rh positive factor by transfusion and by pregnancy. Once sensitised, a further transfusion of Rh positive blood may produce a severe, even fatal reaction. If a pregnant Rh negative woman has been previously sensitised, her infant may suffer from haemolytic disease of the newborn.

It is a simple matter to prevent sensitisation from transfusion with incompatible blood and the reaction which may result from a further transfusion. Such accidents can be eliminated if *only Rh negative blood is used in transfusing Rh negative individuals.*

The other result of sensitisation is the diseased or stillborn infant. While it may not always be possible to save the severely affected child, the survival rate has been increased to approximately 90% in some centres. In Britain this can mean the saving of the lives of some two thousand babies who would otherwise be doomed to death. This has been achieved by the recognition of sensitisation in the pregnant woman and by immediate treatment of the newborn, anaemic infant.

(The writer wishes to thank the Blood Grouping Laboratory of Boston for the use of the diagrams, and Sharp and Dohme Inc. for the velox print of the original art work.)

Malaria—a Momentous Discovery

IN January this year an announcement was made which settles at last a problem which malariologists have been investigating since the beginning of this century.

As some readers will know, the life history of the human malarial parasites is divided into two cycles:

(a) There is a *sexual cycle* in the female mosquitoes which transmit malaria; it begins with the male and female sexual phases being sucked in by the mosquitoes from human blood and ending with the minute, elongated *sporozoites*, which assemble in the insects' salivary glands and are injected back into human blood by the mosquitoes.

(b) A *non-sexual cycle*, which takes place inside the red blood cells of man. This amounts to repeated multiplication of the parasites by a simple process of division. The attacks of malarial fever coincide with the onset of this division of the parasites.

Until the beginning of this century it was thought that the sporozoites injected by the mosquitoes into human blood immediately penetrate into the red blood cells to begin their non-sexual cycle in these. Some doctors, however, began to doubt this. They found, when they were treating people suffering from the disease called general paralysis of the insane by inoculation of the patient with malarial parasites, that if patients were given sporozoites only, quinine given during the incubation period of malaria failed to kill the parasites, and even when it was administered later it only temporarily relieved the symptoms and did not *prevent* the infection. These facts suggested that the sporozoites which were injected did not enter the red blood cells at once, but went to some other part of the body in which quinine did not affect them.

This supposition was strengthened when it was further found that, if large numbers of red blood cells infected with malarial parasites were given to a patient free from malaria, that patient got malaria very quickly and his blood would always infect other people free from malaria; whereas, if sporozoites only were given to persons free from malaria, those persons did not develop malaria until the incubation period had elapsed.

It became necessary, in view of these facts, to find out definitely whether the sporozoites injected by the mosquitoes did or did not pass first to some other part of the body before they entered the red blood cells. Malariologists all over the world have been investigating this problem for many years, and light upon it came first from the study of malaria of birds (chickens and canaries). This very interesting work to which British, American, Italian and German workers all made valuable contributions, cannot be summarised here. One outcome of it was the discovery that the sporozoites of the malarial parasites of birds go, when the mosquitoes inject them, not to the red blood cells, but into large phagocytes of the skin, spleen and perhaps other organs and there pass through three or four generations of what are called *exo-erythrocytic phases*. (This clumsy term means simply that these phases are outside the red blood cells (erythrocytes) and some workers prefer to call them more simply, but slightly less accurately, *tissue phases*.) The next problem was to find these tissue phases in the mammalian hosts such as man and the monkeys which also harbour certain species of malarial parasites.

Until 1947 the search for tissue phases in mammalian hosts was unsuccessful; but last year Dr. P. C. C. Garnham found them in monkeys. Professor H. E. Shortt, Dr. Garnham and their collaborators of the London School of Hygiene and Tropical Medicine have now found them in both monkeys and man, and this is the momentous discovery to which the first sentence of this article refers.

For their work on monkeys, Professor Shortt, Dr. B. Malamos and Dr. Garnham used the malarial parasite called *Plasmodium cynomolgi*, which is very similar to the human parasites. First they infected large numbers of mosquitoes by feeding them upon a rhesus monkey infected with this malarial parasite. When the mosquitoes' salivary glands were full of sporozoites, they were allowed to feed on a malaria-free rhesus monkey, and then all the mosquitoes were ground up in monkey blood plasma and injected into the same monkey. Seven days later the organs of the monkey were examined and in the liver large tissue forms of the malarial parasites were found.

More important than this is the further work done by Professor Shortt, Dr. Garnham and Dr. Covell. This work was made possible by the co-operation of a patient at the Bucks County Mental Hospital, Aylesbury, who needed treatment by the bites of mosquitoes infected with human malarial parasites. This patient and his wife agreed to the doctors' requirements and thus joined the great company of human volunteers who have contributed to the advancement of medical knowledge. The patient was transferred to the Horton Hospital for Mental Diseases, where the Ministry of Health's Malaria Laboratory is situated. There large numbers of mosquitoes infected with the parasite which causes benign tertian malaria (*Plasmodium vivax*) were allowed to feed upon him and the sporozoites from the salivary glands of the mosquitoes were also injected into his blood. Seven days later material was taken under anaesthesia from his liver and in this material tissue forms of *P. vivax* were found.

There seems now, therefore, to be no doubt that the sporozoites of the human malarial parasites, like those of the species which infect monkeys and birds, pass, when they are injected by the mosquitoes, not to the red blood cells, but to cells in other parts of the body, such as those of the liver, spleen and, in birds at any rate, the skin and there undergo a part of the life cycle which is necessarily omitted from all the illustrations and descriptions of this life cycle printed in text-books. The problem which has puzzled malariologists throughout this century is thus answered, and the work of Shortt and his colleagues will take its place with that of Manson, Ross, Grassi and all the others whose labours have gradually elucidated the puzzle of the malarial life cycle since Laveran discovered the malarial parasites themselves in 1880. Whether this completion of the life history will help the control of malaria no one can yet say. Experimental work alone can show whether these tissue phases of the parasites can be controlled by anti-malarial drugs known to us (see DISCOVERY, March, 1945) or by new drugs. We shall need also to find out all the situations in the human body in which these tissue phases can survive and how long they can persist. Clearly there is plenty of work ahead before the full significance of this work by Shortt and his colleagues can be even foreseen.

Geoffrey Pyke, who died on February 23, was an extraordinary personality, an inventor whose imagination was never curbed by attention to practical details. It was Pyke's axiom that "a human being could reason his way through any problem". Professor Bernal has described him as "one of the greatest geniuses of his time", while *The Times* called him "one of the most original if unrecognised figures of the present century". In response to numerous requests from readers for an appreciation of Geoffrey Pyke we publish this article. It is written by the Cambridge crystallographer who worked on the Habakkuk project, which grew out of one of the most remarkable proposals this theoretical inventor ever put forward.

An Inventor of Supreme Imagination

M. F. PERUTZ

THE recent tragic death of Geoffrey Pyke has robbed us of one of the most original characters in this country, a man whose brain was a firework of ideas, some brilliant, some fantastic, but all new and highly unconventional. Pyke cultivated unconventionality in every form; he expressed it in his manner, in his style of writing and in his way of life. His appearance and his conversation were striking. He was tall, dark and wore a goatee; his eyes were thoughtful and serious. He opened his talk with a volley of provocative remarks, trying to size you up by your reaction. If he felt you were sympathetic he took you into his confidence and shared with you, as between one great man and another, the secrets of his latest scheme which was to revolutionise the methods of warfare or to establish human society on a new basis.

Pyke's fundamental belief in the possibility of effecting great changes by a stroke of the pen ran counter to the temperament of his countrymen, most of whom he found to abhor innovation in any form. Hence his contempt for the unimaginative conservativism of the average man which he embodied in his derisive motto: "Nothing must ever be done for the first time." Pyke shared H. G. Wells' belief that people's smugness was largely the result of a faulty system of education which he held to be specially devised for discouraging the habit of original thought. It was as an educational reformer that Pyke achieved the only success which has proved of lasting value. In this article, however, I want to dwell chiefly on his work as an inventor and strategist.

If Pyke's spiritual home was in the clouds, his physical abode consisted of a succession of makeshift lodgings where he camped among littered heaps of books, papers and cigarette ash. It was to one of these that I was summoned by an urgent message in the spring of 1942. Pyke, with an air of mystic importance, asked my advice on the digging of tunnels in glaciers, indicating that he was acting on behalf of Lord Louis Mountbatten, then Chief of Combined Operations. As I learnt later, Pyke had proposed that a force of Commandos should be dropped on a Tyrolean glacier where they should establish an underground base for raids on neighbouring roads and railways. Pyke thought that such a force would constitute a thorn in the flesh of the Germans and would tie down many times their own number of enemy troops—at any rate judging by the experience of the Austrian and Italian armies during World War I which had shown the difficulty of dislodging quite small forces from glacier strongholds. The project, though ingenious, was eventually dropped, because experienced officers considered even British Commando troops to be no match for the expert mountain troops with detailed knowledge of local conditions which the Germans would be able to muster.

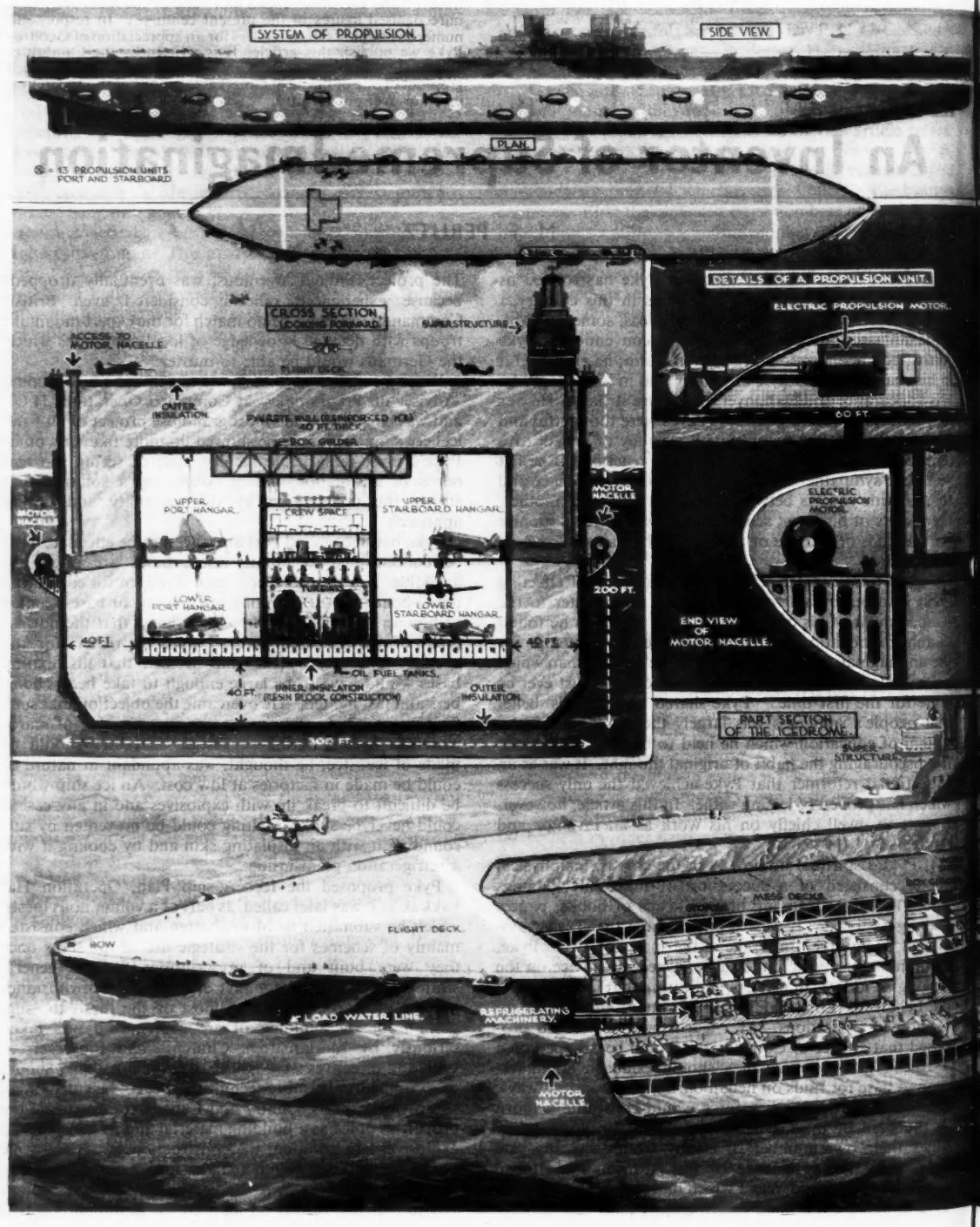
When I saw Pyke again six months later he had become 'Adviser on Programmes' at Combined Operations H.Q., and was engaged on the most grandiose project of all—the iceberg ship. This scheme showed up more than any other Pyke's most remarkable faculty: that of seeing the real needs of a situation and of conceiving a solution that strikes the imagination by its originality and daring approach.

Pyke had recognised that air power, to be effective, must be concentrated at points where bases are often not available. For invasions of distant shores or for combating the U-boats, the creation of large floating air bases seemed to him an obvious necessity. Pyke knew that the normal types of carrier-based aircraft were no match for the enemy's land-based planes and decided that his floating bases would have to be large enough to take heavy bombers and fast fighters. He overcame the objection that such floating islands would involve the excessive use of scarce materials by the daring suggestion that they should be made of ice. Ice, he thought, was abundant in nature or could be made in factories at low cost. An ice ship would be difficult to break up with explosives and in any case it could never be sunk. Melting could be prevented by surrounding it with an insulating skin and by cooling it with a refrigeration plant inside.

Pyke proposed the Iceberg-ship Plan, Operation Habakkuk as it was later called, as part of a voluminous thesis, which he submitted to Mountbatten and which consisted mainly of schemes for the strategic use of the ships once they were built and of prescriptions for the general strategic and political conduct of the war. Notwithstanding the utopian character of most of the thesis the suggestion for the building of an iceberg ship was taken seriously by Mountbatten, Churchill and the chiefs of staff, and directives were issued that the possibility should be examined in its more technical aspects. Scientists were set to work in this country and Canada to investigate the properties of ice as a building material and its resistance to explosives. In addition, the construction of a small-scale model ice ship was begun at Lake Jasper in the Canadian Rockies.

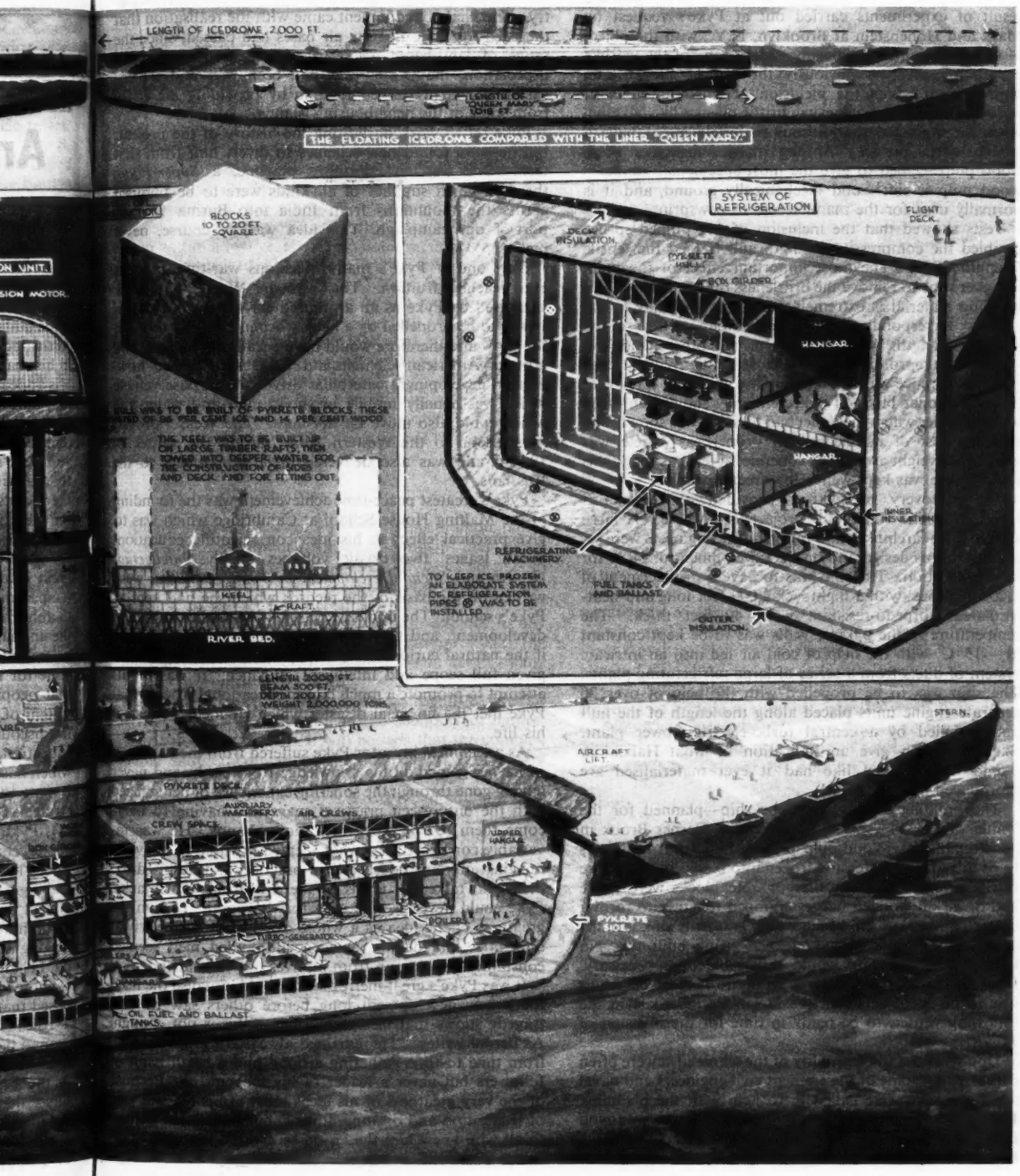
The first test results on ice were so disappointing that

Habakkuk—Pyke's Iceberg Ship



. . . a work . . . which ye will not believe, though it be told you.

(*from a verse in the book of Habakkuk*)



the whole project would have been abandoned there and then, had not the scene suddenly been transformed by the appearance of *Pykrete* (Pyke's concrete). This was the result of experiments carried out at Pyke's request by Mark and Hohenstein at Brooklyn, N.Y., with the object of strengthening ice artificially. Mark, one of the world's experts on plastics, obviously thought of the striking improvement which the inclusion of small amounts of fibrous materials can achieve in brittle plastics like bakelite, when he suggested that fibrous materials might have a similar effect on ice. Among many substances tried, wood pulp seemed to give the most spectacular results—wood pulp is soft wood mechanically ground, and it is normally used for the manufacture of newsprint.

Tests showed that the inclusion of 4% pulped spruce doubled the compressive strength and trebled the tensile strength of ice. The most important effect of the pulp, however, was to remove the brittleness of ice. Pure ice as a building material is extremely unreliable and may fail at stresses corresponding to no more than a fifth of its average strength. With pykrete, on the other hand, test results were reproducible within close limits. While a large block of pure ice was shattered by the impact of a revolver bullet, a similar block of pykrete merely showed an insignificant crater where the bullet had hit it. It was soon found that in most of its mechanical properties pykrete was weight for weight as good as concrete, at least as long as its temperature was kept well below freezing point.

The discovery of pykrete provided a tremendous stimulus to the Habakkuk project as a whole. A large staff of naval architects and refrigerating engineers were set to work on its design and on the development of plans for its construction. The ship was to have a displacement of 2,200,000 tons, with a flightdeck 2,000 feet long and heat-insulated, torpedo-resistant walls 40 feet thick. The temperature in the pykrete walls was to be kept constant at —15° C. with the help of cold air fed into an intricate system of ducts from a series of large refrigerating plants. The ship was to be propelled with the help of over 20 separate engine units placed along the length of the hull and supplied by a central turbo-electric power plant. Sketches which give an indication of what Habakkuk would have looked like had it ever materialised are reproduced on pp. 148–9.

The building of the prototype ship—planned for the winter of 1943–4—was to take place at Corner Brook in Newfoundland. Wood-pulp provided by local mills was to be mixed with water and frozen into blocks in a 200-acre refrigerating plant. The first pykrete blocks were to be laid down on wooden barges cramped together to form a large floating platform which would gradually sink into the water as the mass of pykrete was being built up. No launching of the ship would thus have been necessary. Once the prototype was built an entire fleet of bergships was to be constructed on the North Pacific coast in the following winter, to be ready in time for the invasion of Japan.

Doubts about the feasibility of the whole idea were often expressed by some of the eminent civil engineers and naval architects who were called in to help with the planning. In actual fact the project was doomed as soon as we found out that no accessible place on this earth was cold enough to let Nature do the job of freezing the pykrete, since the amount of refrigerating plant needed to freeze 2,200,000 tons of this material in one winter would have seriously taxed even the large capacity of the American steel industry. The final abandonment came with the realisation that the need for large floating air bases had passed, since the range of land-based aircraft had increased beyond all expectation, the U-boat war had been won and the invasion of Japan seemed feasible by providing air cover from some of the neighbouring islands.

Pyke set to work on writing the history of the project, but he soon found new schemes to divert him from that task. One was an enormous pipeline, a *Super-Pluto*, through which supplies of all kinds were to be pumped across the mountains from India into Burma in support of our campaign. This idea was, of course, never realised.

Only one of Pyke's many ingenious war-time projects ever reached fruition. This was the Weasel, originally visualised by Pyke as an armoured car for snow warfare. It was to be propelled by a helix worming its way through the snow and therefore would have been immobile on solid ground. American scientists and engineers succeeded, however, in developing a caterpillar-driven all-purpose vehicle which was equally mobile in snow, mud and water and which could also move on dry land. The Weasel proved most useful to the Western Allies during the winter of 1944–5, and was also delivered in large numbers to the Russians.

Pyke's greatest peace-time achievement was the founding of the Malting House School at Cambridge which was to give practical effect to his ideas on scientific education. Susan Isaacs' two classic volumes on the *Intellectual Growth* and *Social Development in Young Children*, were written on the basis of the records which she had kept at Pyke's school. The books are fascinating studies in human development, and they show how much can be achieved if the natural curiosity and enterprise of small children is given full scope and intelligent guidance. It was in his attempt to promote a much bigger educational scheme that Pyke met the financial disaster which clouded the rest of his life.

As a technical inventor Pyke suffered from the handicap of having gained all his knowledge from books and never having gone through the sobering experience of being faced with the unforeseen practical snags and having to overcome them by the work of his own hands. He was invariably convinced that what seemed possible to his vivid imagination must be feasible in practice, and despised the men who talked in terms of the proverbial brass tacks. Pyke could never see the trees for the wood. To him the greatness of the idea as a whole overshadowed the trivial difficulties and details which small-minded men seemed constantly to bring up from motives of personal spite.

It was Pyke's great merit that he could visualise the need for a new development long before others saw it. His tragedy shows that in a technical age this is not enough. As Bernal writes: "He remained always the knight-errant, from time to time gathering around him a small band of followers but never a leader of big movements. Because of the very greatness of his ideas most of his life was one of frustration and disappointment, but he has left behind to all who knew him the vision he created for making all things possible."

Bacteria that destroy Concrete and Steel

K. R. BUTLIN, B.A.

MAN in his pride likes to consider himself as a David triumphing over the Goliath of Nature, and there is considerable justification for this attitude. Occasionally, however, the roles are reversed, and the smaller and simpler forms of living organisms unexpectedly enjoy a temporary advantage over the strongest works of man. One normally expects structures of iron and of concrete to last for very long periods but, in certain special but unfortunately all too common circumstances, both iron and concrete can be completely disintegrated by bacterial action within a few years. So we find that concrete sewers are being destroyed, gigantic cooling towers are put out of commission and miles of buried iron pipes distributing water, gas and oil, are rendered useless. At the moment no really satisfactory countermeasures can be taken. There is no doubt that the balance will eventually be restored, and for this full knowledge of the processes involved is necessary. In recent years a considerable amount of research into both problems has been carried out, with the result that we now know what organisms participate and, in the main, how they operate. The next step lies in devising and applying preventive measures.

The Sulphur Cycle

All the organisms involved have as a common factor the necessity for sulphur or its compounds in their metabolism and for this reason they play an essential part in the sulphur cycle in nature. It will be appropriate, therefore, first of all to consider this wider aspect of their activities, for their deleterious actions are due not to any abnormality in their own behaviour, but merely to the change in their normal environment brought about by the intrusion of iron or concrete.

Fig. 1 illustrates diagrammatically the main features of the transformation of sulphur in the economy of nature. Starting from the bottom, it will be seen that the complex organic sulphur compounds in plants are degraded by bacteria or digested by animals to hydrogen sulphide, which is then oxidised by bacteria first to sulphur and then to sulphates. The sulphates are usually assimilated by plants and used by them for the synthesis of sulphur-containing proteins, but in certain special circumstances, very relevant to the corrosion of iron, sulphate, together with sulphur, is reduced directly to hydrogen sulphide by a special group of anaerobic organisms. The oxidation of sulphur to sulphates is carried out by a group of aerobic bacteria called *Thiobacilli*, of which the two chief species are *Thiobacillus thioparus* and *Thiobacillus thiooxidans*. These are the two organisms chiefly concerned in the corrosion of concrete. They resemble each other in being able to oxidise thiosulphates (which are often present in soils) and sulphur to sulphate, but whereas *Th. thioparus* is able to grow in an alkaline medium (pH* 8·5), *Th. thiooxidans* can only develop in acid conditions (pH 6·5 or below). This difference is of great significance in the corrosion process and should be kept in mind. There are other bacteria in the soil which are able to oxidise thiosulphates, but not sulphur, to polythionates and sulphates in even more alkaline conditions (pH 10) than can *Th. thioparus*: these also take part in the corrosion of concrete.

Th. thiooxidans (see Fig. 2) is one of the most remarkable, in some ways the most remarkable, of living organisms. It can live in purely inorganic surroundings, it not only can but *must* synthesise its entire complicated system of vitamins, enzymes and protoplasm from carbon dioxide and mineral salts—in technical language, it is an obligate autotroph—and it is capable of growing in 7% sulphuric acid, which is decidedly toxic to most forms of life. In favourable circumstances it can produce, from sulphur and mineral salts, as much as 10% sulphuric acid and still survive. It will be readily understood that if such an organism finds conditions favourable for growth on concrete, the latter will suffer badly. In the soil, of course, there are normally plenty of materials to neutralise the acid, and the sulphates produced are easily assimilated by plants. In addition, these bacteria help to render soil minerals available to plants by converting insoluble phosphates to the soluble form. They are, in fact, essential and beneficial to soil fertility.

Sulphate-reducing bacteria are very widespread in nature and may be found in practically every type of soil. They are responsible for the colour of the Black Sea by the production of black ferrous sulphide, for the odour of Dutch canals and for numerous other activities, many of them reprehensible. There is a great stretch of mud, two hundred miles long and twenty-five miles wide, off Walvis Bay, South Africa, which periodically releases large amounts of hydrogen sulphide, causing great destruction of fish. These bacteria have been known to invade Californian homes causing blackening of paint and silver ware. They contaminate coal gas and increase the deleterious

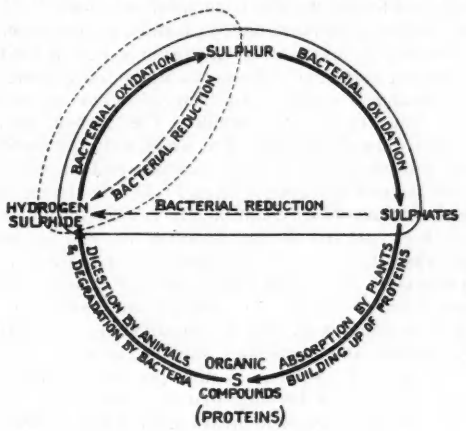


FIG. 1.—The Sulphur Cycle in Nature.

* The pH scale is used to indicate *degree* of acidity. Neutrality—neither acid nor alkaline—is represented by a pH figure of 7. Solutions with pH values above 7 are alkaline, those below are acid. The pH figure represents the logarithm of the reciprocal of the hydrogen ion concentration of the solution.

sulphur content of oil. Finally and most unexpectedly, they are essential agents in the anaerobic corrosion of iron and steel pipes buried in the soil.

Corrosion of Concrete

Concrete is a mixture of sand, cement, gravel and water. The sand and gravel may be regarded as inert materials held together by the hydrated cement compounds. When newly made, concrete is very alkaline (pH 11–12·5) owing to the liberation of calcium hydroxide. On exposure to the atmosphere, carbon dioxide is absorbed, calcium carbonate is first formed and this, in a moist atmosphere, is gradually converted into bicarbonate. Eventually a stable slight alkalinity (pH 8·4) is established.

The corrosion of concrete sewers has been fully investigated by Dr. C. D. Parker of Melbourne, Australia. What follows is taken mainly from his publications.* The corrosion takes place in the space above the liquid level where the concrete is exposed to hydrogen sulphide given off by the sewage. Most of this hydrogen sulphide is the result of the action of sulphate-reducing bacteria on the inorganic sulphates in the sewage. The hydrogen sulphide is an essential agent in the corrosion process; no corrosion takes place in its absence. In the early stages a white deposit forms and flakes of calcium sulphate begin to peel off. At this point the surface of the concrete is slightly acid (pH 6·5). The acidity then increases enormously and the concrete begins to break up into large lumps of soft material containing the gravel and sand embedded. At different stages of the process, Dr. Parker has isolated three types of bacteria:

(1) a miscellaneous group capable of oxidising thiosulphates to polythionates and sulphates at high alkalinities (pH 10),
(2) a species closely resembling (perhaps identical with) *Th. thioparus* and
(3) a species very similar to *Th. thiooxidans* which he aptly calls *Th. concretivorus*.

In addition, by exposing sterile blocks of concrete to an atmosphere of hydrogen sulphide, he obtained evidence that thiosulphates and polythionates as well as elementary sulphur are formed by purely chemical reactions.

By combining the microbiological and chemical evidence, Dr. Parker explains the whole corrosion process as follows. The alkaline surface of the concrete in the space above the liquid sewage is subjected to chemical action by carbon dioxide and hydrogen sulphide. The carbon dioxide gradually reduces the pH to 8·4, while hydrogen sulphide forms thiosulphates and polythionates and in so doing renders the concrete almost neutral (pH 7·5). In the early stages of this combined chemical attack, when the alkalinity is still high (pH 10), the first group of bacteria begins to flourish and slowly to oxidise thiosulphates to polythionates and sulphates. As the pH falls to below 9, mainly through chemical action, *Th. thioparus* finds conditions favourable for growth and rapidly oxidises thiosulphates to sulphates, polythionates and elementary sulphur, causing a fall in pH to below 5. Sulphur is now present in significant quantity and it is at this stage that *Th. concretivorus* comes into action. It develops in great numbers and oxidises the sulphur to sulphuric acid. When the acidity reaches a certain concentration, more sulphur is formed chemically and provides more material for the bacteria to convert into sulphuric acid. Concentrations of free acid as high as 5% accumulate and the concrete disintegrates.

It might well be asked how the particular organisms taking part in this complicated process happen to be there at the right time and why no other ordinary types seem to be taking part. Very many varieties of bacteria are introduced by airborne dust particles, others by splashings from the sewage, which contains a very mixed and plentiful microflora. Those which are deposited on the concrete above the liquid level find themselves in an almost completely inorganic environment containing plentiful supplies of sulphur compounds, and only those types capable of growth in such special conditions are able to survive. Most micro-organisms require organic material for their life processes and these soon die off, leaving the field clear for the various types of *Thiobacilli* which live on inorganic materials, and which flourish as conditions change to suit the different varieties. The concrete, with its atmosphere of hydrogen sulphide, selects its own microflora and accomplishes its own destruction.

A similar but much more spectacular example of concrete corrosion was recently reported.† The interiors of two enormous concrete cooling towers were found to be seriously damaged and on investigation the nature of the corrosion and the type of bacteria isolated appeared to be identical with those described by Dr. Parker. In this particular instance it would be possible to prevent corrosion by eliminating hydrogen sulphide from the towers, but apparently this method is neither easy nor cheap. Another suggested preventive method is the sterilisation of the water circulating in the towers and it may be possible to incorporate bacterial poisons in the concrete.

Corrosion of Iron and Steel

Numerous factors can contribute to the external corrosion of ferrous pipes buried in soil—acidity, stray currents from electric installations, differential aeration, high salt concentration and so on. But the most widespread and dangerous form of soil corrosion in this country occurs in neutral water-logged clays and marshy soils from which air is virtually excluded. In many such cases the corrosion is so severe that replacements are necessary after a few years' service, in extreme cases after only a year. There have been recent examples in which about 20 miles of pipe line running through clay have had to be replaced, at a cost of £40,000. The problem, then, is quite serious from an economic point of view, and one must add to this the inconvenience and disruption of supplies caused by it.

Fig. 3 illustrates a characteristic example of anaerobic corrosion of a cast iron pipe which had been buried in clay for about 6 years. The surface skin has been removed on a lathe in order to show the effect. In the dark patches the iron in the cast iron, which contains 3–4% carbon, has been leached out leaving a matrix composed chiefly of

*C. D. Parker. The Corrosion of Concrete. *The Australian Journal of Experimental Biology and Medical Science*. Volume 23, pp. 81–98.

Species of Sulphur Bacteria associated with the Corrosion of Concrete. *Nature*, March 29, 1947, p. 439.

† C. B. Taylor and G. H. Hutchinson. Corrosion of Concrete caused by Sulphur-oxidising Bacteria. *Journal of the Society of Chemical Industry*, February, 1947.

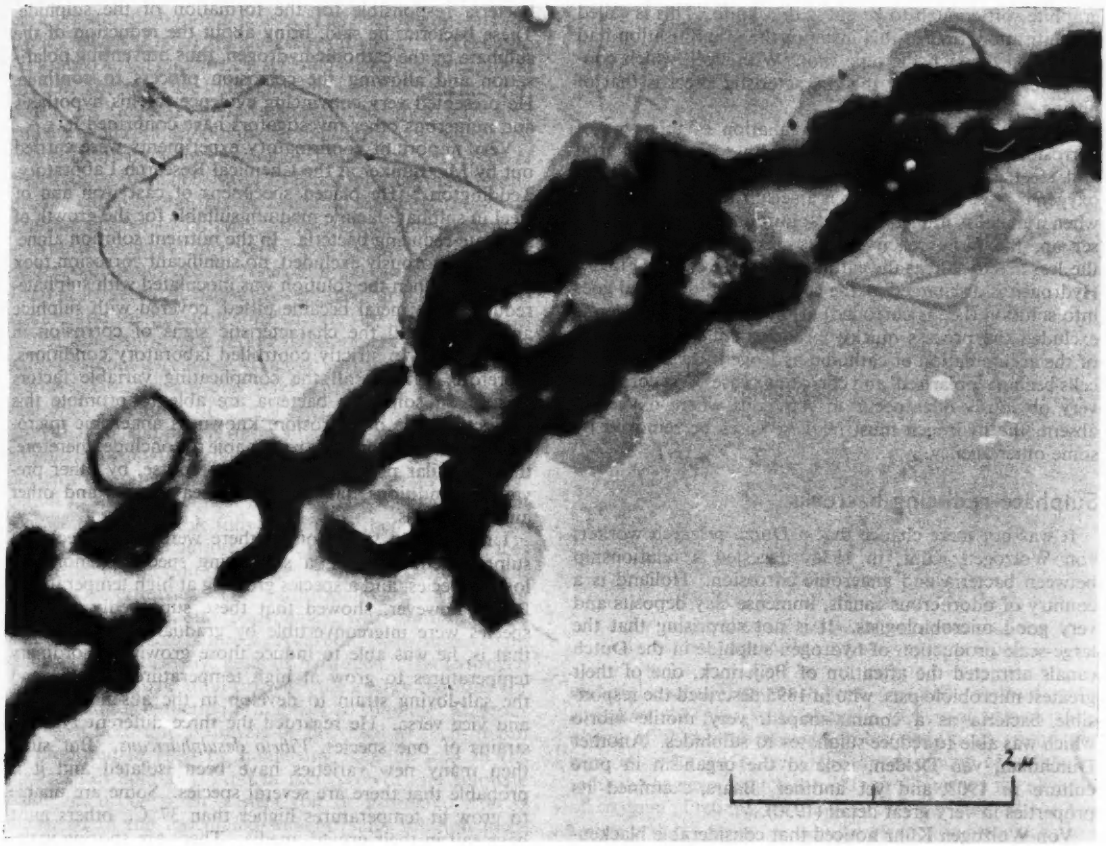
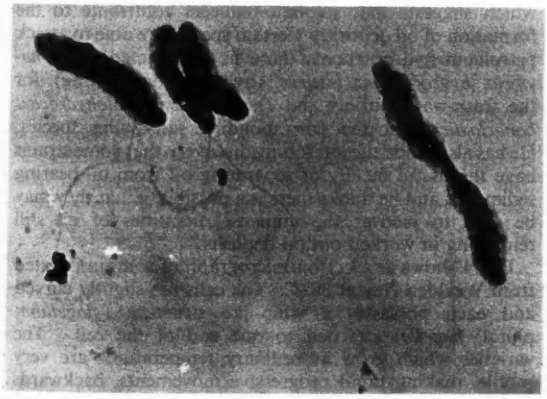
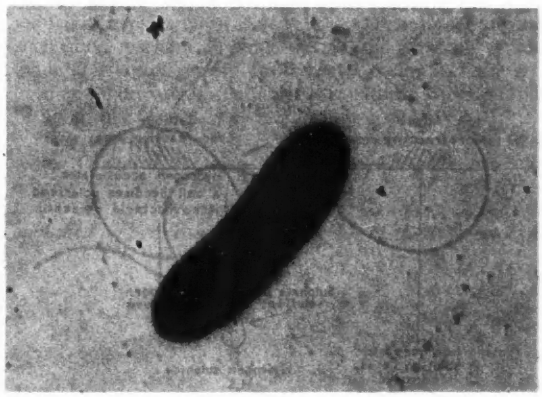


FIG. 2.—This electron micrograph shows *Thiobacillus thiooxidans* which causes corrosion of concrete. Magnified 22,500 times.





Two different strains of the sulphate-reducing species, *Desulphovibrio desulphuricans*. FIG. 3 (*left*).—Specimens of a strain isolated from Wealden Clay at 35°C. Note the whip-like flagellum at one end of the cell. Magnified 10,000 times. FIG. 4. (*right*).—This thermophilic (heat-loving) strain was isolated at 55°C. from garden soil. It differs markedly from the other strain; the cell is larger and bears several scattered flagella. Magnified 14,500 times.

graphite soft enough to be cut with a knife. This is called graphitisation, and in this instance the graphitisation had penetrated through the pipe wall. With steel, which contains very little carbon, the characteristic effect is that of pitting.

Until 1934 no satisfactory explanation of this type of corrosion was forthcoming. Normally corrosion of iron and steel cannot take place in neutral solutions unless oxygen is present. Corrosion is an electrochemical process: when a metal is immersed in a solution 'galvanic' cells are set up, the more reactive areas becoming the anodes, the less reactive areas the cathodes of these cells. (Fig. 5.) Hydrogen is discharged at the cathodes and the metal goes into solution (i.e., is corroded) at the anodes. If oxygen is excluded the process quickly becomes stifled on account of the accumulation of cathodic hydrogen: the electrolytic cells become 'polarised' and corrosion ceases. As corrosion very obviously does occur in clay soils where oxygen is absent, the hydrogen must in these cases be removed by some other agency.

Sulphate-reducing bacteria

It was not mere chance that a Dutch research worker, von Wolzogen Kühr, in 1934 suggested a relationship between bacteria and anaerobic corrosion. Holland is a country of odoriferous canals, immense clay deposits and very good microbiologists. It is not surprising that the large-scale production of hydrogen sulphide in the Dutch canals attracted the attention of Beijerinck, one of their greatest microbiologists, who in 1895 described the responsible bacteria as a comma-shaped, very motile vibrio which was able to reduce sulphates to sulphides. Another Dutchman, van Delden, isolated the organism in pure culture in 1903, and yet another, Baars, examined its properties in very great detail (1930).

Von Wolzogen Kühr noticed that considerable blackening of clay often occurred round the corroded pipes and quite often there was a black crust of iron sulphide on the parts affected. This gave him the clue to the unknown mechanism of anaerobic corrosion. He suggested that the cathodic hydrogen was removed by the action of the

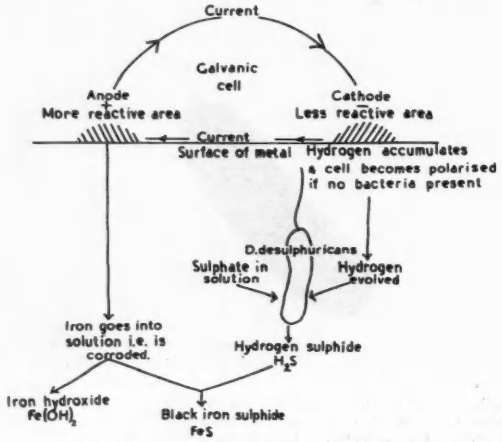


FIG. 5.—The course of reactions involved in the microbiological corrosion of iron.

bacteria responsible for the formation of the sulphide. These bacteria, he said, bring about the reduction of the sulphate by the cathodic hydrogen, thus preventing polarisation and allowing the corrosion process to continue. He presented very convincing evidence for his hypothesis and numerous other investigators have confirmed it.

Very important confirmatory experiments were carried out by Mr. Bunker at the Chemical Research Laboratory, Teddington.* He placed specimens of cast iron and of steel in sulphate-lactate medium suitable for the growth of sulphate-reducing bacteria. In the nutrient solution alone, with air rigorously excluded, no significant corrosion took place, but when the solution was inoculated with sulphate-reducers, the metal became pitted, covered with sulphide and showed all the characteristic signs of corrosion in heavy clays. In strictly controlled laboratory conditions, therefore, without all the complicating variable factors existing in soils, the bacteria are able to promote this distinctive type of corrosion, known as anaerobic microbiological corrosion. It is reasonable to conclude, therefore, that a similar process, modified, of course, by other prevailing conditions, takes place in heavy clays and other anaerobic soils.

Until 1930 it was thought there were three species of sulphate-reducers, i.e., a salt-loving species, a non-salt-loving species, and a species growing at high temperatures. Baars, however, showed that these supposedly different species were interconvertible by gradual acclimatisation, that is, he was able to induce those growing at ordinary temperatures to grow at high temperatures (55° C.) and the salt-loving strain to develop in the absence of salt, and vice versa. He regarded the three different types as strains of one species, *Vibrio desulphuricans*. But since then many new varieties have been isolated and it is probable that there are several species. Some are unable to grow at temperatures higher than 37° C., others must have salt in their growth media. There are sporing varieties, others cannot be induced to form spores. Professor ZoBell of the Scripps Institution of Oceanography, California, has made a special study of the various types associated with petroleum. He has accumulated evidence which suggests that sulphate-reducers contribute to the formation of oil deposits. Certain species are able to attack petroleum hydrocarbons: these he has named *Desulphovibrio hydrocarbonoclasticus* (hydrocarbon-splitting) for the fresh-water variety and *Desulphovibrio halohydrocarbonoclasticus* for the corresponding salt-loving species. He has also made the interesting discovery that some strains have the useful faculty of separating oil from oil-bearing sediments, and he thinks there is a possibility that they may be used to recover the immense quantities of oil still remaining in worked-out oil deposits.†

Fig. 4 shows an electron-micrograph of a strain isolated from Wealden clay at 30° C. The cells are slightly curved and each possesses a whip-like structure (*flagellum*; plural, *flagella*) attached to one end of the cell. The varieties which grow at ordinary temperatures are very motile, making rapid progressive movements, backwards and forwards, sometimes in circles, and presenting a very

* H. J. Bunker. Microbiological Experiments in Anaerobic Corrosion. *Journal of the Society of Chemical Industry*, March, 1939.

† C. E. ZoBell. Bacterial Release of Oil from Oil-Bearing Materials. *World Oil*, August 25 and September 1, 1947.

fascinating picture under the microscope, especially when dark ground illumination is used. The heat-loving (*thermophilic*) species (Fig. 5) are markedly different. The cells are very much larger and possess several flagella scattered round the cell. They also are motile but in a very different manner: instead of rapid progressive movements, they turn over and over and rotate about their longitudinal axis. One would normally attribute this difference in motility to the type of flagellation, for it has always been supposed that flagella are the cause of motility in bacteria. Recently, however, Professor Pijper of Pretoria, South Africa, threw a bombshell into the world of microbiology by producing strong evidence that they are the *result*, not the cause, of motility. Even more recently, other workers have disputed his contention and the question still remains very open.

The most surprising recent development in our knowledge of sulphate-reducers is due to two American research workers, Drs. Starkey and Wight, who were able to show that *impure* cultures of sulphate-reducers were capable of growth in a completely inorganic medium, i.e. of autotrophic growth. They stated, however, that the results were not entirely satisfactory owing to contamination of their cultures. At the Chemical Research Laboratory, Teddington, we have been able fully to confirm their conclusions.* Very stringent precautions were taken to exclude all traces of organic matter and the cultures remained pure throughout the experiments. The autotrophic growth medium contains sulphates and phosphates, with sodium bicarbonate as the sole source of carbon, with ammonium chloride and, normally, gaseous hydrogen. The hydrogen is essential; its oxidation provides the energy required for growth and for reduction of sulphate to sulphide. Gaseous hydrogen need not, however, be provided as such: it can be produced *in vitro* by immersing metallic iron in the mineral salt solution. And in fact, growth and sulphate reduction occur when a steel rod or powdered iron is immersed in the inoculated mineral salts solution incubated anaerobically with no added hydrogen. These experiments are additional evidence for the theory that sulphate-reducers are the active agents in the cathodic depolarisation process occurring in the anaerobic corrosion of buried ferrous pipes.

Methods of Protection

Various methods can be employed to protect pipes passing through aggressive soils, none of them completely satisfactory. Perhaps the best procedure that can be advised in our present state of knowledge is that the pipe shall be protected by a bituminous coating of ⅛ inch thickness, preferably reinforced with an inert binding material such as microasbestos. Another method is to surround the pipe with about 9 inches of gravel. The object of this is to ensure aerobic conditions round the pipe in order to prevent the development of sulphate-reducing bacteria, which can only proliferate in the absence of oxygen. Perhaps the most promising method for the future is that known as cathodic protection, in which bars of metal such as zinc and magnesium are attached to the buried pipe-line: the corrosion is transferred to the bars which act as anodes and are easily and more economically replaceable. The ideal solution of the problem would be to use a pipe material not susceptible to attack by sulphate-reducing bacteria, but it is not easy to find a material with such good mechanical properties as iron or steel. Pipes made of asbestos cement are, however, being increasingly used and there are plastics such as polythene which would be admirable were they economically possible.

FIG. 6.—This cast iron pipe shows corrosion caused by bacteria. It had been buried six years in clay soil.

*K. R. Butlin and M. E. Adams. *Nature*, August 2, 1947, p. 154.

(*This article is published by permission of the Director of the Chemical Research Laboratory. The three electron micrographs were taken by Mr. J. Trotter of the Metallurgy Division, National Physical Laboratory, and are published by permission of the Director of the Laboratory.*)

The Importance of Particles

I. BERKOVITCH, M.Sc., A.R.I.C.

EACH year over two million tons of small particles add to Britain's costly smoke pall. This is an example of small particles uncontrolled and in the wrong place being a nuisance—sometimes they are a menace. But particles in the right place can give us many advantages including, for instance, the beautiful effects of modern lacquers. To minimise the nuisances and extend the advantages we must first know how to measure their quantity and size range. We can then go on to consider the significance of the results we get.

In general one and a quarter per cent of the weight of coal used in Britain is discharged into the air as smoke. About one half of this comes from domestic grates, although these use only about one quarter of the coal. The universe, too, contributes to our atmospheric dust by the millions of meteors—about 20 million per day—which enter the earth's atmosphere. Almost all of these disintegrate before reaching the earth, producing what may be called cosmic dust. On the earth itself weathering, corrosion, trituration and solution followed by evaporation all add to the quantity of dust. This may be called the earth-formed dust, and although it varies a great deal it tends to be siliceous. Dust from cosmic sources tends to be metallic or stony or both.

The whole dust system by the interplay of gravity and air currents is in constant dynamic movement. Despite the general impression that rain clears the air by causing dust to settle, American studies showed no decrease in atmospheric dust either during or after rain. Certain types of particles are well known for the health hazards and fire risks associated with them. Workers in dusty trades, for instance, are liable to diseases of the lungs. The Registrar General's reports on occupational mortality show that the seven deadliest occupations are all ones, which may lead to pulmonary tuberculosis, pneumoconiosis and other respiratory diseases. These industries include the mining of coal, tin, copper and slate, sandblasting and pottery kiln operation.

There are also dusts which are systemic poisons such as T.N.T. and compounds of lead, manganese and cadmium. They act directly on the vital organs. Severe lead poisoning never follows the simple handling of solid lead but only exposure to dust fumes. English factory inspectors have also emphasised that factories handling dusty manganese ores had poisoning cases; but with good dust control no poisoning occurred.

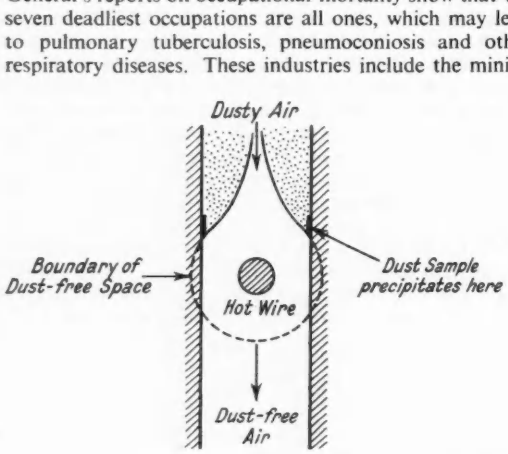
Pollens and certain other organic matter which is in a divided state may produce allergy in susceptible individuals. Hay fever and asthma are complaints of this type.

Dust-borne organisms became a source of anxiety to the health authorities, particularly in the crowded shelter conditions of 1940 and 1941. Spray techniques and impregnation of blankets were used to reduce the stirring up of dust, minimising the concentration of air-borne organisms.

Some materials, when finely divided, represent a greatly increased fire- and explosion-risk for two main reasons. Firstly, they settle slowly, if at all, and can readily be disturbed. Furthermore, the fine division provides a very great surface area on which chemical reactions, including rapid oxidation, can take place. Studies on the combustion rate of various materials have shown a big increase in the rate of combustion with decreasing particle size. A whole range of industries handling common inflammable materials have discovered the seriousness of these factors and had to take steps to meet them. Coal dust, which has been the cause of many pit explosions, now has limestone and calcium chloride mixed with it to minimise this risk. Flour dust sometimes produced serious secondary explosions during the war, after high explosive had blown the material into a cloud. This explosive tendency was suppressed by adding a mixture of limestone and sodium bicarbonate to the flour.

Cotton-seed, resin, aluminium and starch are other materials which are normally considered harmless or only slightly dangerous. In powdered form, however, all of these have been the source of serious factory explosions.

It is interesting to note that, as with vapours, inflammable powders dispersed in air have to be above a certain concentration to be dangerous. For instance, flour dust thinly dispersed in air will not burn.



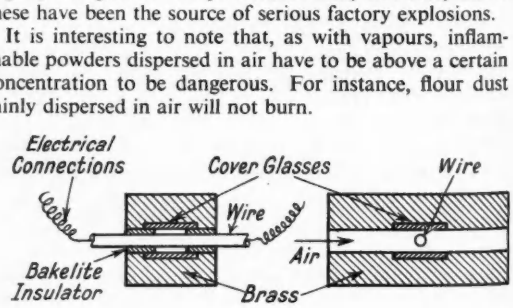


FIG. 1. (*Left*).—The principle of the Thermal Precipitator used for taking dust samples from the air in mines, etc. Around a hot wire there is an approximately spherical dust-free space; particles moving towards the wire cannot enter the dust-free barrier, and collect in the region indicated. FIG. 2. (*Right*).—In the instrument itself the dust samples are collected as linear deposits on cover glasses; these are then examined under the microscope. In the left-hand diagram, the sampling device is viewed in the direction of air flow; right, view at right-angles to air flow.

The dust danger is the greater since dusts can acquire an electric charge when carried by an air current, and a discharge may then cause the dust to explode. The voltage of 5000 produced on dry brown coal carried in a current of dry air is typical for these conditions. Under moist conditions the voltage may fall to 2000. To counteract this danger, nitrogen may be used to replace air as the dust 'carrier' where electrostatic discharges are frequent.

Sizes of Particles

Particles are measured in units derived from the metre. Those which are most important are the *millimetre* (one thousandth [10^{-3}] metre), the *micron* (one millionth [10^{-6}] metre) and *Angstrom units* (one ten thousand millionth [10^{-10}] metre). The Greek letter μ is commonly used in this connexion and stands for a micron.

Particles with sizes between 50 microns and tens of millimetres include a wide range of common materials ranging from cement and coal to pharmaceutical powders. Particles of sizes below a fifth of a micron are below the limit of visibility by an ordinary optical microscope. Some pigments, fumes and smokes are in this category. But by using the electron microscope, one can 'resolve', that is, separate the images of particles down to less than a hundred Angstrom units, and some research workers have obtained resolutions down to 10 Angstroms. Fine aerial dust, large molecules such as those of starch and collodion and finer portions of mine dust are in this category.

The surface area relations of particles are very important. If a 1-millimetre cube is subdivided into smaller cubes, the amount of surface exposed increases at a surprising rate. A cube has six faces, and the initial surface area of the cube will be six square millimetres. If each edge if divided into ten and the cube split into new smaller cubes, the new surface is 60 square millimetres. It is evident that particles of very small size may represent relatively large surface areas. One sample of finely milled rock had a surface of 165,000 square centimetres per gram of material. It is this enormous surface that causes particles to have properties that are so different from those of the same material in bulk.

Small particles are affected by molecular bombardment, their consequent irregular jumping being known as Brownian movement. Particles of gamboge water-colour emulsified in water show this effect, as does tobacco smoke in air. Calculations based on an analysis of this movement have been used to find the actual number of molecules present in standard quantities of materials.

Because direct methods of measuring minute particles are very tedious and slow, indirect methods have been developed which are satisfactory for industrial control purposes. Most of them give comparative and not absolute results. In all cases, of course, the information required is the range or distribution of the sizes of particles. This is sometimes a new idea to those who think of measurements as absolute or unique figures. In fact, it is true of all measurements, but the large numbers of single units involved in matter composed of particles brings this point home very vividly. In some cases shape, too, is important.

FIG. 3.—The chimneys of British homes and factories send up two million tons of particles a year to pollute the atmosphere. This picture shows what a month's fall of soot in the County of London (area about 120 square miles) would look like if swept up into a pile in Trafalgar Square (*Courtesy, National Smoke Abatement Society*).

One very ingenious sampling device, the thermal precipitator, is claimed to give 100% efficiency of sampling for particles up to at least 20 microns. This device is based on the observation that there is a dust-free space surrounding a hot wire. Cover glasses line a narrow channel containing a hot wire, and conditions are adjusted so that the boundary of the dust-free space extends (theoretically) outside the channel. Thus, no dust will be able to pass the wire. Representative non-aggregated deposits occur a little towards the inlet side of the precipitator. This instrument is used for such purposes as the obtaining of dust samples in mines.

Sieving and Sedimentation

Sieving is a familiar sizing method which is direct but not individual. The nearer particles are to spheres, the fewer the irregularities produced during the sieve analysis.

The analysis is carried out by building a small tower of sieves of varying fineness, coarse being at the top. The sample is placed on the top sieve and the tower of sieves agitated for some standard period. Shaking machines are often fitted with time switches to give fixed sieving times. The portion on each sieve is then weighed. It is evident

that for control and comparison purposes, sieving must always be carried out under the same conditions.

The smallest size which can be dealt with by common sieving equipment is about 300 mesh B.S.S. (British Standard Specification), equivalent to 53 microns, as openings smaller than this are blocked by the sample. New equipment using high-frequency agitation by electromagnets is claimed to sieve satisfactorily down to 700 mesh (20 microns) and is used in the preparation of soft face powders.

Indirect methods of measurement are based on dispersing the particles in a fluid and measuring their movements under various conditions or how much they block the passage of light.

The most widely used industrial method for particles below sieve range is by sedimentation. A known quantity of powder is uniformly dispersed in a liquid and allowed to settle under the influence of gravity. Since the laws of settling are known, one can calculate the proportions of various size groups in the original by weighing samples withdrawn at a known depth. But there are difficulties because the laws are based on spheres, which rarely occur in practice. Also, as particles fall they displace liquid which flows up and exerts an upward drag on them. For these and other reasons, the settling method as normally used in industry gives only an indication of absolute size with results probably $\pm 5\%$ of the 'true' results.

An adaptation of this method known as photosedimentation, claimed to give great accuracy, uses a very dilute suspension to ensure completely free settling. Under carefully controlled temperature conditions, a 0·0005% suspension is allowed to settle and the tracks of a large number of individual particles recorded photographically. These tracks are directly measured, the separate sizes calculated, and hence the distribution.

Measuring Surface Area

Specific surface is defined as the surface area per some unit quantity, e.g. square centimetres per gram. In many processes, such as catalysis or gas-solid reactions, this is a more significant factor than particle size distribution; of course, it is related to the latter, but also depends on such features as fissures, pores and re-entrant angles. Here, too, there are many methods of measurement available, each with its own limitations. Permeability of a bed of sample when liquid or gas is passed through it is found to give a measure of the specific surface. The method has been successfully used, for instance, as a routine check on the properties of dusts used in insect control in the food industry.

Adsorption of gases or of solutes from solution has also been successfully used in measuring surface area. In the gas method, for instance, the sample is de-gassed, then the 'monolayer capacity' is evaluated. This is the quantity of gas which can be taken up in a completely full layer one molecule thick adsorbed on the solid. By making certain assumptions concerning the area occupied by each adsorbed gas molecule, an estimate of the surface area can be made. Different sizes of adsorbate molecules give different results.

Light-extinction methods are also used for measurement of surface area. A beam of light is passed through a cell and its intensity compared in the absence or presence of obscuring particles. The greater the surface area, the lower the intensity of light passing through the suspension, the surface area being proportional to the log of the reciprocal of the intensity.

The philosophical implications of some of the methods are very interesting. If the determination of total surface area by adsorption methods depends on the material adsorbed (the adsorbate), then in no sense can one refer to a 'true' value, but only to one appropriate to the intended application of the powder.

So widely used are particles in industry that it is difficult to avoid making a recital of their applications seem like a catalogue. From the wide field of their uses, a few examples are chosen. The radio valve and associated industries require powders for at least nine different groups of applications. Tungsten, used for filaments, is produced as powder before being sintered into rods; molybdenum passes along a similar route before becoming wire or sheet; fine emitter powders are used for coating the valve cathode, and alumina the cathode heater; phosphorus powder 'getters' glowlamps to high vacuum, while fluorescent powders give high efficiency to discharge lamps. Experience has shown the necessity for close check and control over the particle size distribution of these materials in order to obtain satisfactory lamps and valves.

The chemical engineer designing de-dusting plant for cleaning gases, or investigating the filterability of a slurry is equally interested in this property. The graph shown alongside indicates the performance of various types of gas cleaning apparatus used to clean blast furnace gas.

Paint systems are, of course, exceedingly complex, the simplicity of basic composition being in marked contrast with the complexity of the system produced. In addition to being of a specified colour, a paint must possess at least general stability, sufficient flow to avoid showing brushmarks, and rapid 'set' to avoid running during the drying period. The dry film must be durable, opaque, adherent, flexible, hard and glossy or not as required. Chemical interaction between pigment and medium, and selective adsorption of constituents of a medium by the pigment are only two of the many factors to be taken into account in addition to particle size distribution and particle shape. It is clear that fundamental knowledge of paint systems will be derived only from simultaneous consideration of a great number of factors—including, of course, shape and size distribution of the pigment particles.

Chocolate manufacture demands control of particle shape rather than size. Smoother cocoa particles produce a pleasing palatable texture, rougher ones having the opposite effect.

Powdered metals are often used in industry. Certain small parts, for instance, may be economically made by moulding metal powders, a technique to which the term 'powder metallurgy' is applied. For some special purposes non-metallic materials can be conveniently introduced into metal parts by the use of powders of both. For instance, carbon can be used with copper for the current-collecting brushes of electric motors, or a self-lubricating bearing can be made by sintering together copper and tin with graphite and then soaking this porous bearing in oil. This will often last the life of the machine. It is obvious that the use

of metal as particles gives greater flexibility and has many other advantages for particular applications.

Dust Removal

The law may at times be an ass, but it is very wise in laying limits to the noxious materials that may be discharged into the air. The gases issuing from cement kilns or blast furnaces, for instance, may be heavily laden with dust—perhaps up to 42 grams per cubic metre. Sometimes for its own profit—in recovering valuable material—more often to comply with the law, industry uses equipment to remove dust from gases passing into the atmosphere.

Baffles and filters are well known as dust removers. Zigzag baffles can be used to remove dust, but the most widespread example of their use is to trap fine water particles in air-conditioning plants. Air is drawn through a very fine water spray which has to be removed before the air passes on to the fan. Passing it through the baffles effects this removal.

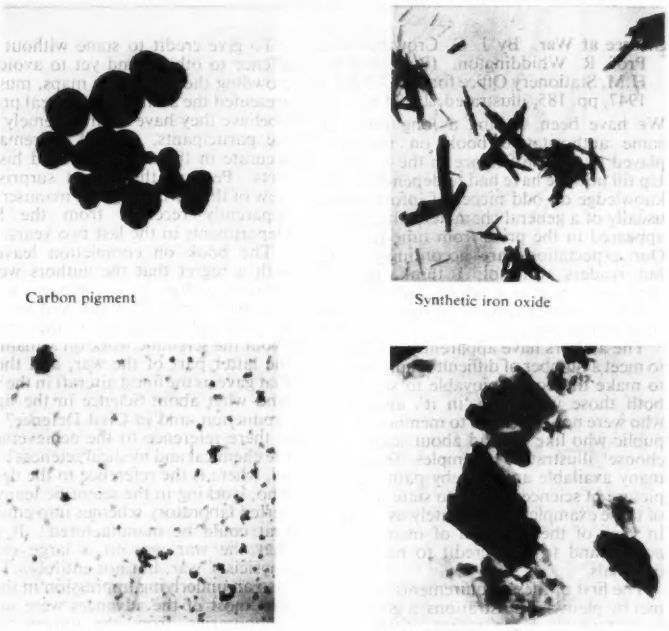
Where the gases are neither hot nor corrosive cloth filters may be used. More severe conditions are met by the use of asbestos, glass or woven metal cloths. The cloth itself forms a base which quickly becomes coated with the collected material, so that the latter eventually becomes the filter medium and determines the properties of the equipment. By arranging for frequent mechanical shaking of the filters, filter units can become automatic and be left unattended for long periods.

In industrial areas one often sees cyclones—the industrial not the meteorological variety—although few people seem to know their function. The dust-laden air enters the cylinder part of this device at a tangent, passes round and downwards, and throws out most of its coarse dust. The relatively dust-free air then passes out through a centre vertical duct.

Spray towers are also used to remove dust from gases. They may be packed with inert material like coke to ensure intimate mixing of the spray passing downwards with the gas passing upwards and be fitted with baffles to keep the gas in a whirling motion and continually impinging on the wetted baffles.

Mechanical washers disperse the spray in the path of the dusty gas by means of rotating paddles.

Electrical methods have been used to remove—among others—sulphuric acid mist, boiler flue-dust and various metallurgical fumes. They are based on the principle that the particles either have an electric charge or can be given one by an electrode. The gas, which is laden with particles, is passed between two electrodes maintained at a high potential difference, which may go up to 50,000 volts, and is unidirectional. The efficiency of this device may approach 100% removal of all suspended matter, but most practical problems require some combination of these devices.



Carbon pigment — Synthetic iron oxide

Prussian Blue — Graphite

FIG. 4.—These electron micrographs of paint pigments (magnification is 10,000 times) were taken at the Paint Research Station, where the electron microscope is being used in the study of paints. Nearly all pigment particles prove to be angular; particles of carbon black are a rare exception to this general rule, being spherical in shape. (*From the proceedings of Symposium on Particle Size Analysis, organised by Institution of Chemical Engineers and Society of Chemical Industry. Paint Research Station copyright.*)

When forced ventilation is used it is normally advisable, and sometimes essential, to remove dust particles from the air. In addition to the use of ventilation in public places and factories to increase human comfort, it is also applied to the cooling of machines such as turbo-alternators and larger motors. In these cases the dust concentration is much less than those encountered in the processes mentioned above. Filters are used, either dry or covered with oil, to promote adhesion of the dust. Some designs embody cheap 'throw away' filter elements which are replaced from time to time. The dry filters give greater efficiency in removing particularly fine material, but the viscous film filters permit much higher throughput. Whichever is used depends on the particular conditions to be met.

Throughout industry there is a tendency to supplement or replace fallible human judgment by objective testing. Users of particles share in this movement, and investigations of the significance of particle size analyses proceed alongside more extensive adoption of analytical methods. The increased understanding derived from such work points the way to great progress in these fields.

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Perry, *Chemical Engineers' Handbook*. McGraw Hill, 1941. (Section on 'Mechanical Separations').

Dallavalle, *Micromeritics*, Pitman, 1943.

Papers presented at a symposium on Particle Size Analysis, organised by the Institution of Chemical Engineers and Society of Chemical Industry, 1947.

The Bookshelf

Science at War. By J. G. Crowther and Prof. R. Whiddington. (Published by H.M. Stationery Office for the D.S.I.R., 1947, pp. 185, illustrated, 2*s.* 6*d.*)

WE have been waiting a long time for some authoritative book on the part played by British Science in the last war. Up till now we have had to depend for our knowledge on odd pieces of information, usually of a general character, which have appeared in the press from time to time. Our expectations are accordingly high, but readers will not, I think, be disappointed in it as a whole, although inevitable omissions will be noticed and regretted by many.

The authors have apparently attempted to meet a number of difficult requirements: to make the book enjoyable to scientists, both those who were 'in it', and those who were not, as well as to members of the public who like to read about science; to choose illustrative examples from the many available and thereby paint a wide picture of science at war; to state the facts of these examples as accurately as possible in view of the dispersal of many of the actors; and to give credit to named individuals.

The first of these requirements has been met by plenty of illustrations, a good style of writing which recaptures a little of the excitement that stimulated the imagination and energy of scientists through long hours of work, and here and there a human story. Some readers would probably like to know more of the human side but the task of weaving this in with the interesting and necessary technical material is obviously a difficult one. Only rarely, such as in the descriptions of the polar distribution of energy radiated by the special aerials of radar sets, do the authors provide rather 'heavy going' for the lay reader, although in these passages there is good meat for the scientist.

The choice of radar for pride of first place in science at war is an obvious one. This story of what was mainly a British achievement occupies half the book but even so it has been necessary to omit some very interesting details. However, the account as it stands covers the major achievements of radar and even succeeds in describing the working of the magnetron in language that will be understood by most lay readers.

There follows next a good, but perhaps relatively long, section on Operational Research, another important British achievement. The third section on the Atomic Bomb is of special interest. It is now two and a half years since the remarkable book *Atomic Energy*, by H. D. Smyth, appeared in the U.S.A. and was reprinted in this country. This did not, however, attempt to show the part British Science played in the achievement, and this third section makes a useful supplement.

The final section on 'Science and the Sea' will show how far removed naval warfare is now from the 'gun-versus-armourplate' days. Attack and defence have largely departed from the surface of the sea to the media above and below.

To give credit to some without giving offence to others, and yet to avoid overcrowding the book with maps, must have presented the authors with a real problem. I believe they have been extremely fair to the participants, as well as remarkably accurate in their technical and historical facts. Perhaps this is not surprising in view of the 'scrubbing' the manuscript has apparently received from the Service Departments in the last two years.

The book on completion leaves one with a regret that the authors were not allowed another 50 to 100 pages to tell us something about 'Science and the Land', and more about the war in the air. What about the scientific work on armaments in the latter part of the war, and the work that gave us the finest aircraft in the world? And what about Science in the fight for production, and in Civil Defence? Where is there reference to the achievements in the chemical and medical sciences? Above all, where is the reference to the designers who, working in the scientific teams, converted laboratory schemes into equipment that could be manufactured? It is true that the war was to a large extent a physicists' war, but not entirely. There is also an underlying impression in the book that most of the advances were made by 'temporaries' from the universities and from industry, and an enquiry into the truth of this impression might in itself be of value. We still need to have more books of this kind, even though this one has skimmed the cream off the milk.

CHARLES GOODEVE.

This Great and Wide Sea. By R. E. Coker. (North Carolina University Press; Geoffrey Cumberlege, London, 1947; pp. 325 with 91 plates and 23 text-figures, 27*s.* 6*d.*)

THIS book is packed with useful information skilfully presented in an easy style that avoids unnecessary technicalities. It appears to have been written chiefly for students and other interested persons having little or no special training in marine biology or oceanography and succeeds admirably in providing for their needs. The 'discovery' of the sea, the growth of oceanographical investigation, the chemistry and physics of sea water, and the sea as an environment for living organisms all fall within the scope of this single volume of 325 pages which is also copiously illustrated with photographs and line drawings.

Most of the photographs are quite good and helpful to the text, but a few are of very poor quality and others are quite irrelevant. Some of the line drawings, too, are not very successful. Fig. 11, on page 200, appears to have suffered rather badly in reproduction, and Fig. 23 on page 278 conveys little or nothing of value concerning the otter trawl and the method of working it. Errors in the text appear to be few and can easily be corrected when a new edition is called for—as no doubt it will be. It is rather surprising though, to find on page 34 the statement that R.R.S. *Discovery* and *Discovery II* carried out their famous researches in the Arctic; they worked, of course, in the Antarctic. But these faults are of minor importance and do not seriously detract from the value of this really fine book.

G. A. STEVEN.

The Art of Identifying Birds: Bird Recognition—I. Sea-Birds and Waders. By James Fisher. (Penguin Books, Harmondsworth; 2*s.* 6*d.*)

THE amateur contribution to the advance of biological knowledge has, I suppose, been greater in the sphere of ornithology than in the study of any other group in the animal kingdom, with the possible exception of entomology. The main reasons for this are almost certainly (*a*) that birds are mainly diurnal and (*b*) that they can be readily identified in the field, even by comparative beginners. The same factors make butterflies the most popular group among amateur entomologists. Thus large numbers of people to whom the killing of birds is repugnant are able to make field observations with the full assurance that it is not going to be necessary to back their identification with a dead bird as a 'voucher specimen'.

With no more elaborate equipment than a pair of field-glasses, and often only with sharp eyes and ears, a large body of keen amateur bird-watchers have been able to make observations that have bulked largely in the sub-structure of facts on which such professionals as David Lack and R. E. Moreau have recently been able to make striking advances in our knowledge of ecology, genetics, population-control and other aspects of zoology, with particular reference to birds. Moreover, such outstanding ornithological names as those of Eliot Howard, H. F. Witherby, F. C. R. Jourdain and Admiral Lynes are those of complete amateurs as far as biological training is concerned.

In his ambitious new Pelican series, of which Volumes II (game-birds, waterfowl and birds of prey) and III (perching and singing birds) have still to appear, James Fisher, sometime Secretary of the British Trust for Ornithology, and already author of one of the most valuable books for the field ornithologist, *Watching Birds*, sets out to help the amateur bird-watcher again by summarising all the existing information on the field identification of British birds. He seeks, in his own words (and his own italics), to provide a pocket-book which will enable 'the thousands of bird-watchers in Britain to-day . . . to recognise not only a bird's *kind*, but also its *place in nature* and its *general importance*'. He fully acknowledges his debt to *The Handbook of British Birds*, and indeed since that great work was completed in 1941 no worker in this field can avoid quarrying in it to some extent. The plan of *Bird Recognition* is to provide for each bird a page of text on its field characters, breeding habits, world distribution and migrations, together with a useful note on further reading; a map compiled by W. B. Alexander showing the distribution in the British Isles by vice-counties (these

must be used with care in some cases, as one occurrence since 1900 qualifies for inclusion; there is, of course, no significance in the fact that the gannet has occurred in Cambridgeshire but not in West Suffolk within that period!); an ingenious circular chart summarising seasonal information about breeding and migration; and a drawing by "Fish-Hawk". These last are, unfortunately, somewhat uneven in quality. There are also keys to the field characters of both the sea-birds and the waders, which will appeal to those who like this somewhat acrostic method. While, however, it is possible to criticise certain aspects of the book, the summaries of field recognition characters alone make it invaluable for all who wish to identify birds in the field, both for those who are starting out on that fascinating pursuit, and for those who are already well launched on a bird-watching career, but can never remember, say, the exact way of distinguishing between a green and a wood sandpiper.

R. S. R. FITTER.

Drugs from Plants. By T. I. Williams. (Sigma Books, London, 1947; pp. 119 + 12 plates, 6*s*.)

SIGMA BOOKS have again produced a very useful and readable book. Dr. T. I. Williams is deputy editor of *Endeavour* and might therefore be expected to know how to make his subject matter interesting; he has certainly not failed in this respect. The subject of the book is fully implicit in the title—the use in the treatment of disease of substances derived from plants. Quinine, hashish, digitalis, penicillin, ergot, opium and cocaine form the subject matter of the main chapters but the reader finds more than the dry bones of chemistry and pharmacology in their pages. If one may judge by his book Dr. Williams is a scholar and antiquarian as well as a scientist. All sorts of queer facts and ancient prescriptions are assembled for those who enjoy the flavour of antiquity. For although every reader may be expected to be familiar with some at least of Dr. Williams's curiosities none may be expected to know them all.

The chapter on penicillin, although overlapping to some extent the chapter in Duthie's *Molecules against Microbes*, makes a useful contribution to the subject in setting Fleming's discovery against a background of earlier reports of biological antagonism—or *antibiosis* as the antithesis of symbiosis is now called. Pasteur himself, we learn, was aware of this phenomenon.

The purely factual scientific parts of the book are brief, clear, accurate and informative. Neither are they unnecessarily technical. In this respect, however, one mild criticism arises: is it necessary for all popular books involving chemistry to devote a section to the explanation of formulae? Surely the reader not already familiar with them will skip it, for the use of formulae cannot be learned in one lesson—it is a habit based on practice.

R. G.

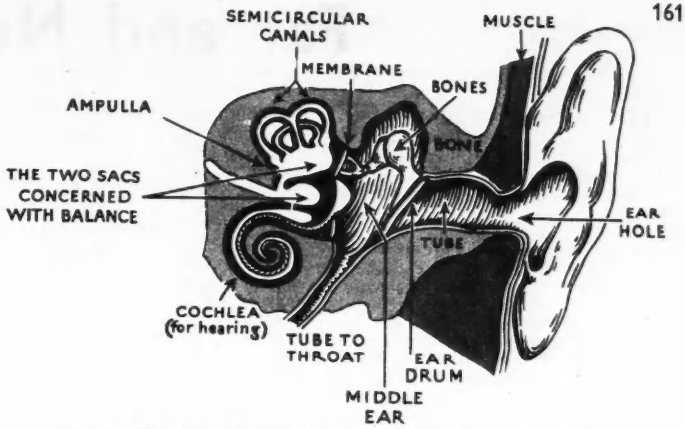


Fig. 1.—This section through the ear shows how the three semi-circular canals and the two 'balancing' sacs are arranged.

JUNIOR SCIENCE

How the Ear Works—II

LAST MONTH I described how soundwaves in the air make our eardrums vibrate; how the small bones in the middle ear (look at Fig. 1) are also made to vibrate; and how these bones transmit the vibrations to the fluid of the inner ear. I also described how the cochlea is the organ of hearing.

The cochlea is only one part of the inner ear. The rest has nothing to do with hearing; it helps us to keep our balance. If you close your eyes you can still stand or walk upright, and the same applies in pitch darkness; but people with both inner ears damaged may be unable to do so, though in the light with their eyes open they soon learn to keep their balance. Occasionally a patient complains to his doctor that when he bends over he 'feels dizzy', and staggers or even falls over. This sometimes turns out to be due to disease of the inner ear which is preventing the balance organ from working. It is called the washing-basin sign, because it may be noticed first when the patient is bending over to wash his face.

In Fig. 1 you can see that the balancing organs are three semicircular canals and two spaces or sacs. The three canals enable you to keep your balance when you move. If you are standing on a platform that is suddenly tilted you automatically tilt your body and, probably, move one foot, so that you do not fall over. Those movements depend on the semicircular canals. The fluid in them moves slightly when your head moves, and disturbs the hairs of sensitive cells which form part of the inner lining of the canals. Fig. 2 is a diagram showing a group of these sensitive hair cells in the swelling, or ampulla, at the end of a canal.

Sometimes this mechanism is upset. Everyone knows that if you spin round and round quickly and then stop you get dizzy and may fall over; the movement has caused an excessive disturbance of some of the sensitive cells, and so you continue to feel as though you were spinning round even when you have stopped. Too much stimulation of the sense organs of the semicircular canals can cause unpleasant effects, such as vomiting: this happens in sea-sickness, which is due mainly to the action of the movement of the ship on the balancing organs.

Even when you are quite still the position of your head relative to the earth is still important; you may be lying down, or sitting upright; whichever it is, corresponding messages are being signalled from sensitive organs in your inner ears, through the nerves to the brain. The sensitive organs that do this job are not in the semicircular canals; they are in the small sacs (see Fig. 2). The sensitive cells in them have not only hairs, but also minute crystals of calcium carbonate, called ear-stones, which are stuck to the hairs. If the head points downwards, as when you dive, the ear-stones pull on the hairs, and so messages are sent to the nerves connected to the hair cells. A swimmer who dives into deep water turns right way up without any difficulty, even with his eyes closed, and can soon strike out and reach the surface. But a person with a defective inner ear may be in danger if he dives, however good a swimmer he is, because he cannot right himself.

ANTHONY BARNETT.

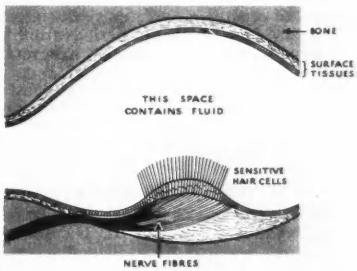


Fig. 2.—This diagram shows how some of the sensitive cells are arranged in part of the balance organ of the inner ear.

Far and Near

The Physical Society Exhibition

THE 32nd exhibition of scientific instruments was held by the Physical Society at South Kensington from April 6–9. Comparatively few really new instruments were shown, but a very marked all-round improvement in design and finish was apparent. The organisers are to be congratulated on their success in excluding a high proportion of the purely engineering instruments which have previously swamped their scientific forerunners.

A striking feature of this exhibition was the number of firms exhibiting instruments with which they are not normally associated. Two electrical component manufacturers, for instance, showed special types of X-ray diffraction cameras, developed presumably for use in their own research laboratories and subsequently placed on the market.

Two new electron microscopes were exhibited. One by Metropolitan-Vickers is a successor to their 50-kV EM2 instrument. The new model (EM3), which operates at 100 kV, is of considerably better external appearance, and its performance shows great improvements in flexibility, although its ultimate resolving power does not appear to be greater. The second instrument was an experimental model by the Plessey Company, very similar in appearance and design to the early American commercial model. Metropolitan-Vickers also showed an experimental recording mass spectrometer which can be used for the analysis of hydrocarbon gases as well as of isotopes. So far no commercial instrument of this kind has been produced in this country, although an American model was first marketed some years ago.

In the high-energy field, a small linear electron accelerator for energies up to 20 million volts was shown by G.E.C., and there were several of the special toroidal vacuum chambers (or 'doughnuts', to use the vivid American term) required for betatrons and synchrotrons.

Industrial instrumentation was clearly the driving force behind a majority of the exhibits, and a favourite this year was the electronic process timer, a device capable of controlling the durations of a series of repetitive operations with great accuracy over a range of periods from a two-hundredth of a second up to several hours.

The appearance of aspherical lenses and of an ultra-violet microscope employing a fused quartz optical system were welcome signs of technical progress in this field.

Death of Professors Bower and Eve

THE death of one of Britain's most eminent botanists, Professor F. O. Bower, occurred on April 11 at Ripon, at the age of 92. When he was a student at Cambridge, British methods of teaching botany lagged far behind the 'new botany' taught on the Continent. At the suggestion of Prof. S. H. Vines he visited Germany, to work under Sachs at Würzburg and then under de Bary at Strassburg, 'the vital centre of academic botany in Germany' at that time. On his return to Britain he became Prof. D. Oliver's assistant at University College, and then a lecturer under T. H. Huxley at the Normal School of Science. During this period and his early years as professor at Glasgow University (he was appointed to the Chair in 1885 and retired only in 1925) he was a leader of the botanical renaissance in this country. His best-known book is *Botany of the Living Plant* which first appeared in 1919 and the fourth edition of which has just been published.

Professor A. S. Eve, the English physicist who succeeded Rutherford at McGill University and who later wrote the authorised biography of Rutherford, died at his home near Godalming on March 24 at the age of 85.

Planes Spray Fertilisers

THIS spring aeroplanes have been spraying artificial fertilisers over big areas of winter grain in Russia. Based near the areas to be treated, the planes fly low and distribute the fertiliser evenly over the thawed soil at a time when the winter wheat and rye are most in need of easily soluble plant foods. In the Kuban grain belt alone aircraft have treated 125,000 acres in this way, states *Soviet News*.

Submarine Gravity Survey in Channel

THE Department of Geodesy and Geophysics at Cambridge University is to make a gravity survey on board H.M. Submarine *Talent* in the English Channel during May 1948. The project is being carried out under the auspices of the Royal Society with the full co-operation of the Royal Navy. The object of the expedition is to obtain information about the structure of the channel basin which should help in interpreting how the geology of southern England and the Continent is related.

The cruise will last for four weeks. Three civilian scientists, Mr. B. C. Browne, Mr. R. I. B. Cooper and Mr. R. L. G. Gilbert will be on board the submarine which will be equipped with special apparatus, some of it lent by the Danish Geodetic Commission. Besides a Vening-Meinesz gravity pendulum, it is hoped to use a new type of gravimeter.

Accurate measurement of this kind can only be made under very steady conditions, and the movement of a surface vessel would make it impossible to make the necessary observations except in a dead calm. A submarine, however, can dive below the waves, and even in rough weather at a depth of 100 to 200 feet the boat is so steady that measurements can be made at sea almost as accurately as on land.

This method of working was originally devised by the well-known Dutch scientist, Professor F. A. Vening-Meinesz and has been used by him to make over a thousand gravity measurements all over the oceans.

New Rector at Imperial College

AIR Chief Marshall Sir Roderic Hill becomes Rector of the Imperial College of Science and Technology as from October 1 in succession to Sir Richard Southwell.

New Colour Film

SHOWING at the British Industries Fair this month was the 'Ektachrome' colour sheet film.

Like 'Kodachrome', this new film gives colour transparencies, in full colour and without screen pattern or mosaic, by straightforward exposures in cameras of standard type. Both 'Ektachrome' and 'Kodachrome' are multi-layer films having three extremely thin superimposed coatings of sensitive emulsion—blue-sensitive, green-sensitive and red-sensitive—which first record and later reproduce the colour components of the subject photographed. At the time of the exposure in the camera the various layers of the emulsion are impressed with latent images which record the blue, green and red components of the subject, and the subsequent processing operations convert these latent images into colour deposits—respectively yellow, magenta and cyan (blue-green)—which together reproduce the colours of the original.

Where the 'Kodachrome' and 'Ektachrome' materials differ is in the development process by which the colour deposits are produced. The 'Kodachrome' film entails the use of a reversal development treatment which is practicable only under scientifically controlled factory conditions. The colour deposits do not pre-exist in the material in any form, but are produced simultaneously with the development of the positive silver image, as a result of chemical reaction between oxidation products of the developing agent and a 'colour couple' which is present in the developer; the need to ensure that each of the three stages of the final image development forms its colour deposit precisely within the depths of the appropriate layer demands precise control, so exposed 'Kodachrome' has to be returned to the factory for processing.

With 'Ektachrome' film the process is radically simplified by the inclusion of the 'colour couplers' in the various emulsion coatings during manufacture, so that with a single process of reversal development each emulsion layer produces the correct colour deposit. For this reason the processing of 'Ektachrome' film becomes a normal photographic routine which can be carried out successfully by the photographer himself. The whole process takes about 90 minutes and produces the finished colour transparency, ready for drying.

'Ektachrome' film, as now being made in this country, is offered as cut-sheet films in the standard sizes up to 4¾ × 6½ in. in the Type B form designed for use with high-efficiency tungsten studio illumination. It is, however, also adaptable for exposure by other forms of illumination, including daylight, by the use of appropriate filters.

DR. T. E. ALLIBONE

MR. J. W. RYDE

PROF. G. W. ROBINSON

PROF. O. R. FRISCH

Royal Society's New Fellows

THE following twenty-five scientists were elected F.R.S.'s at the meeting of the Royal Society on March 18:

DR. T. E. ALLIBONE, director of the Research Laboratories of Associated Electrical Industries, Aldermaston, Berks, distinguished for his contributions to the application of high-voltage phenomena.

DR. F. P. BOWDEN, lecturer in physical chemistry, University of Cambridge, distinguished for his contributions to the study of friction and lubrication.

H. CONSTANT, deputy director (research) National Gas Turbine Establishment, distinguished for his studies in the applications of thermodynamics and aerodynamics to aircraft engines.

DR. S. F. DOREY, chief surveyor, Lloyd's Register of Shipping, distinguished for his contributions to marine engineering.

E. H. FARMER, assistant director and senior organic chemist of the British Rubber Producers' Research Association, Welwyn Garden City, distinguished for his experimental studies of complex unsaturated hydrocarbons and related natural products.

PROF. O. R. FRISCH, Jacksonian professor of physics in the Cavendish Laboratory, Cambridge, distinguished for his researches on fission processes in nuclear physics.

SIR JOHN FRYER, secretary of the Agricultural Research Council, distinguished for his services to agricultural science and his contributions to applied entomology.

PROF. T. M. HARRIS, professor of botany in the University of Reading, distinguished for his researches in palæobotany.

PROF. W. H. HEITLER, senior professor in the School of Theoretical Physics, Institute for Advanced Studies, Dublin, distinguished for his contributions to theoretical physics.

A. L. HODGKIN, assistant director of research in physiology, University of Cambridge, distinguished for his researches on the nature of nervous conduction.

DR. G. M. LEES, chief geologist to the Anglo-Iranian Oil Company, distinguished for his contributions to stratigraphical and structural geology, particularly in relation to oilfields.

PROF. R. A. MCCANCE, professor of experimental medicine, University of Cambridge, distinguished for his contributions to metabolic studies of human beings.

DR. K. MAHLER, senior lecturer in mathematics in the University of Manchester, distinguished for his researches in the theory of numbers.

DR. SIDNIE M. MANTON, lecturer at King's College, London, and Fellow of Girton College, distinguished for her work on the Crustacea and other invertebrates.

DR. DOROTHY M. NEEDHAM, of the School of Biochemistry, University of Cambridge, distinguished for her researches on the biochemistry of muscle. She is the wife of Dr. Joseph Needham, and to the best of our knowledge this is the first occasion that a husband and wife have come to be elected F.R.S.'s.

PROF. J. H. ORTON, professor of zoology, University of Liverpool, distinguished for his investigations in marine biology.

SIR LEONARD PARSONS, emeritus professor of diseases of children, University of Birmingham, distinguished for his studies on child health and the wasting disorders of children.

DR. STANLEY PEAT, reader in organic chemistry, University of Birmingham, distinguished for his contributions to the constitution and synthesis of carbohydrates.

PROF. G. W. ROBINSON, professor of agricultural chemistry, University College of North Wales, Bangor, distinguished for his contributions to the study of soils.

DR. W. A. H. RUSHTON, university lecturer in physiology, Cambridge, distinguished for his researches on the effect of electrical stimuli on muscles and nerves.

J. W. RYDE, senior physicist in the Research Laboratories of the General Electric Company, Wembley, distinguished for his contributions to pure and applied physics.

G. R. S. SNOW, fellow of Magdalen College, Oxford, distinguished for his work on plant hormones and growth.

DR. E. W. R. STEACIE, director, Division of Chemistry, National Research Council, Canada, distinguished for his researches on gaseous chemical reactions.

DR. J. A. TODD, lecturer in mathematics, University of Cambridge, distinguished for his researches into the geometry of figures.

Dr. F. YATES, chief statistician, Rothamsted Experimental Station, distinguished for his contributions to the statistical analysis of agricultural problems.

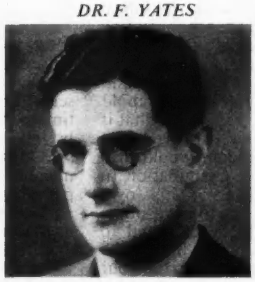
The Biometric Society

THE Biometric Society, a new international organisation, whose aim is the furtherance of quantitative biology in all its aspects by means of meetings and its journal (*Biometrics*), came into being at a conference held in Woods Hole, Massachusetts, during September 1947. Its President is Professor R. A. Fisher, F.R.S., and its Secretary, Dr. C. I. Bliss of New Haven, Connecticut.

For the purpose of more local activities, the Society is organised into regions, of which it is proposed that a British Region shall form one. A provisional committee under the chairmanship of Dr. J. W. Trevan, F.R.S., is now engaged in drafting proposals for the regional organisation and activities, which are intended to bring together biologists and biochemists, who are interested in the application of quantitative methods, with the statisticians and mathematicians who can co-operate in developing these methods. Further information can be obtained from the Regional Secretary, Dr. K. Mather, of the John Innes Horticultural Institution, London, S.W.19.

MR. H. CONSTANT

DR. F. YATES



DR. S. M. MANTON

DR. DOROTHY NEEDHAM

Science Masters meet in Glasgow

THE Scottish Branch of the Science Masters' Association, which was formed as recently as January, 1947, carried through a most interesting programme for its first annual general meeting in the Chemistry Department of Glasgow University from April 1 to April 3.

On the Thursday forenoon the meeting opened very quietly with the business meeting. The Branch showed an increase of membership from 251 to 278 with almost 50 applications under consideration.

The afternoon was given over to demonstrations in the Natural Philosophy, Chemistry, Zoology and Botany Departments of the University. The greatest attraction perhaps was the exhibition by Prof. P. I. Dee and his staff of a million-volt proton accelerator, drawings and diagrams of a 30-million-volt synchrotron among other new apparatus, and a demonstration of the production of artificial radioactive isotopes by neutron bombardment. In botany there was an interesting set of cultures of clover plants on agar agar, some inoculated with effective and some with ineffective nodule-forming organisms. Another demonstration of interest was one in antibiotics concluding with a demonstration of how to imbed plant material in plastics.

The meetings in the evening contained some of the highlights of the conference. Mr. F. A. Meier of the London Institute of Education gave his first of two lecture-demonstrations. The frequent spontaneous applause as he carried out his many clear-cut demonstrations of fundamental principles showed the appreciation of the audience of a superlative teacher and craftsman. Most of his experiments were done with 'home-made' apparatus which was designed with such simplicity and ingenuity that the conclusions to be drawn were never in doubt.

This lecture was followed by a discussion on the topic 'School and University Teaching'. In opening, Prof. John Walton appealed for the teaching of more biology to the great mass of school pupils who were not destined for academic careers. He also expressed the opinion that since biology is the hobby-forming science there is hope that the wider teaching of it would ultimately be a factor in the reduction of gambling. He was followed by Mr. F. G. Daldy of the S.M.A. who felt that the standard for entrance to the Universities should be raised. This he claimed could be achieved if there were a committee responsible for drawing up a national scheme of work for schools in which all dead wood would be eliminated, allowing more modern work to be done which need not be repeated at the university. The silence with which this suggestion was received showed that it found little favour with Science masters. Prof. W. R. Smart then entered a very strong plea for closer liaison between schools and universities, and claimed that every pupil should learn science. He felt there should be a Standing Committee in each subject made up from H. M. Inspectors, Examiners and Schoolmasters. At the universities there should be compulsory general science courses for Art students.

In the open discussion period most speakers agreed with Prof. Smart and disagreed with Mr. Daldy, but most interest was aroused by Prof. Dee who claimed that all education ceased in the Higher Leaving Certificate year and that no civilised community should condone the harm done to the pupils in these very important formative months by the intensive cramming. He called for the abolition of these examinations and said that in his experience the Scottish students arrived at university with less enthusiasm for their subject than their English counterparts. This was the direct result of the Higher Leaving Certificate system.

Sir Hector Hetherington, who presided, in summing up said that he, personally, felt that entry to the university should be simpler. He would demand two things. Firstly a certificate from the school stating that the student had satisfactorily completed a course of secondary education. Secondly, he would set an examination in English to find out if the student could write his native tongue. He argued that if the student could do this it proved that he could think. The student would also be asked to sit a simple examination in one other basic subject of his own choosing and since this was to be a simple exam the student would be expected to score high. In conclusion he hoped the S.M.A. would be able to meet the four universities to bring about the closer liaison desired. It was decided that the Association make the preliminary approaches.

BALD FACTS FROM THE BRITISH ASS

DR. R. E. G. ARMATTOE, of Londonderry, Northern Ireland, whose paper was read to the meeting (of the American Association of Physiologists at Washington), is a student of human hairiness, which varies, he said, with geography and intellect. For some undetermined reason, the most intellectual men are apt to be the baldest. Dr. Armattoe attended the 1947 meeting of the British Association for the Advancement of Science at Dundee, Scotland, and found that 55% of the male delegates showed 'central baldness' and 22% 'frontal baldness'. Swedish intellectuals were found to be in the most desperate shape: 70% of them are bald before they are 40. In Switzerland the incidence of intellectual baldness is only 52%.

Intellectual women have hair problems too, but of a different sort. At the Dundee convention, said Dr. Armattoe, 58% of the female scientists between 21 and 45 showed 'hirsutism in the form of moustaches'. Swedish women are luckier than others. Most of them are as bald on their upper lips as the male Swedes are on their pates. But on the whole, Dr. Armattoe concluded sadly, moustaches are an increasing problem to the cultured young women of Europe.

Time.

Streptomycin and Tuberculous Meningitis

RESULTS which show the efficacy of streptomycin as a cure for tuberculous meningitis were reported in *The Lancet* on April 17. Clinical trials have been going on at Medical Research Council centres, and analysis of the results shows that 27 lives were saved out of the first 105 cases treated. Out of 33 children under three who were treated, 12% were found to be making good progress; 82% had died. Out of 72 older children and adults, 36% were making good progress, and 56% had died.

A Sulphonamide v. Cholera

LAST month's news of the progress on the medical science front included a report about a new sulphonamide that is being tested against cholera. The new compound, known as 6257, which is a condensation product of sulphathiazole and formaldehyde gave encouraging results against cholera germs in mice. It was tried out on cholera patients—being given by mouth—during the course of an epidemic in the Madras Presidency last year, and the report in the *British Medical Journal* (April 17) states that when these patients "were treated in their homes with this drug alone, in the absence of nursing, general medical care and any form of adjustment treatment, the survival rate compared very favourably with that obtained by recognised therapy". 85 patients were thus treated and 82 survived.

German Scientific Literature

AN exhibition of German books, periodicals and newspapers held in London last month made it clear that there is now a regular stream of German scientific and technical journals flowing into this country. Importation and distribution is organised by EPPAC Ltd., 2–5 Studio Place, Kinnerton Street, London, S.W.1, and readers who want to know what scientific literature is being brought from all free zones of Germany should write to this firm for catalogues.

X-Ray Crystallography Summer School

A SUMMER SCHOOL in X-ray Crystallography will be held in September in the Physics Department of the Manchester College of Technology, under the direction of Dr. H. Lipson. Further details may be obtained from the Director of Extra-Mural Studies, The University, Manchester, 13.

Twice as many Science Graduates

IN reply to a recent House of Commons question asking for a comparison of the scientific manpower output at the present time with the estimates and targets set by the Barlow Committee, Mr. D. P. Jay said that the Barlow Committee recommended the doubling of the pre-war output of graduates in science and technology as soon as possible. On the best estimate available this increase would be realised within the next two years and was likely to be maintained thereafter.

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